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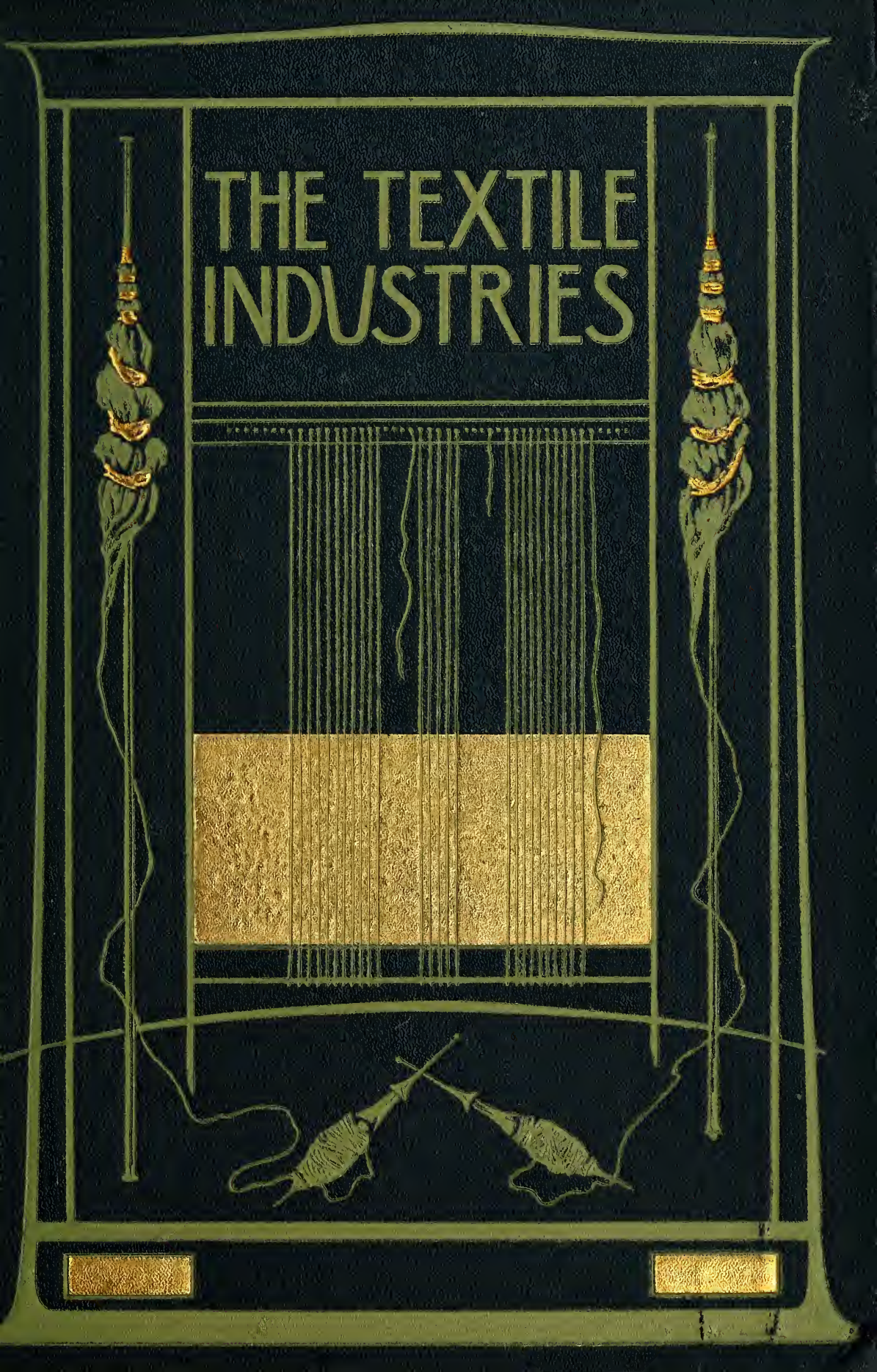

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ALTAR CLOTH, IN DOUBLE-PILE VELVET AND GOLD

(Warner & Sons, Newgate Street, London)

THE TEXTILE INDUSTRIES

A PRACTICAL GUIDE to FIBRES YARNS & FABRICS in every branch of Textile Manufacture

including Preparation of Fibres
Spinning Doubling Designing
Weaving Bleaching Printing
Dyeing and Finishing

BY WILLIAM S. MURPHY
Assisted by Leading Experts in Textile Technology

VOLUME V

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Part IV (*Continued*)

Weaving

CHAPTER IV

The Tappet System of Warp Shedding

Manipulation of the Warp.—Mastery of the warp seems, in the opinion of the younger members of the trade, to imply mastery of the loom. This is a mistake; ability to utilize the power loom springs from knowledge of the whole mechanism. Probably the artistic ambition of the weaver has given undue prominence to warp manipulation. Students at technical colleges show a strong partiality for designing classes in preference to those of mechanics and practical weaving, with consequent futility, in many cases. A designer without a thorough knowledge of the loom is like a general planning a campaign without a knowledge of the country in which his operations are to be conducted. With due regard to the rest of the loom, too much importance cannot be attached to intelligent control of the mass of threads we call warp. For that leases were made; for that the heald shafts were devised; for that were constructed plans of heddling and treadling; for that the immense labour of making harness mountings was undertaken; for that were invented the scores of warp-shedding appliances which are in operation at the present day.

Warp Shedding.—The primary function of the warp mechanism is to divide, or shed, the warp so that the shuttle may pass under the threads intended to appear on the surface of the cloth, and over all those which the pattern requires to be covered by weft. Such a division may be effected in several ways. The threads to be flushed may be lifted above the other division of the warp, which remains stationary; both parts may be drawn from, and return to, the same straight line; the whole warp

may be continuously deflected, those being lifted and those depressed passing directly from the one extreme to the other; or a combination of these different motions may be employed.

Closed or Centre Shedding.—The structure of the loom shows that the primary and most obvious method of shedding is the equal opening of both divisions of the warp from a level centre (fig. 254, 1). The heald shafts are drawn up or pulled down for each pick, and return to a level when the pick has passed. Owing to its age, the advantages of this method of shedding have been depreciated and lost sight of to a certain extent. For one thing, the threads are deflected at no time more than half the depth required for the shed. Say that a shed of 4 in. is needed, then the warp is deflected from the centre 2 in. on each side. When a warp thread breaks, the normal position of the warp affords the weaver an opportunity of mending it without trouble. If an error has been committed in weaving, the web can be readily reversed, and the perfect balance of the warp preserved. For fast weaving, however, the disadvantages of the closed shed are many and serious. For every pick the healds are required to make the double motion of coming to the centre and then rising or coming down; this entails friction and the expenditure of time. A certain degree of unsteadiness is caused by the continual motion of the whole warp.

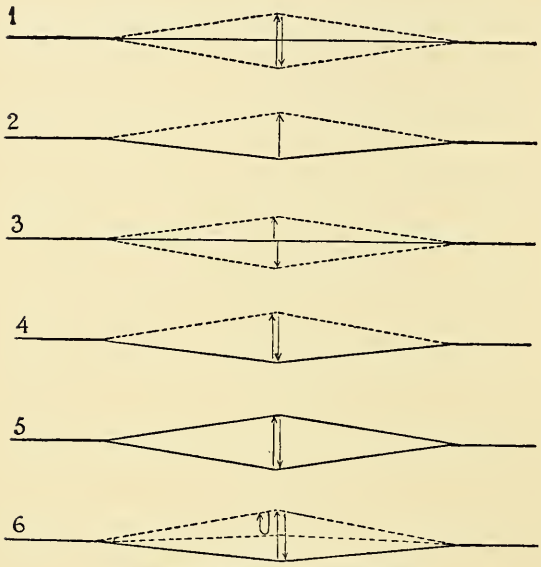


Fig. 254.—Diagrams of Various Sheds

1, Plain weave or through shed. 2, One heddle at a time (warp dipped to equalize strain), common Jacquard action. 3, Rising shed with sinking bottom. 4, Rising and falling shed, bottom stationary. 5, Top and bottom stationary with rising and falling shed. 6, Semi-open shed.

The other closed shed is known as the stationary bottom, the one part of the warp remaining always on one level, while the shed is made by the lifting of the other part (fig. 254, 2). This shed would hardly recommend itself on its own merits. The strain on the lifted warp threads is very great; the time taken is even longer than with the

common centre shed, because one set of threads has to perform the whole traverse; and the power expended is extravagant, the rising shafts receiving no help from the standing ones. But certain tappets, single-lift dobbies, and Jacquards admit of no other method. The earlier and figuring Jacquards could be operated on that principle only. The first example of the method was probably the flowering harness. It is very useful in many ways, though inventors find it a point upon which to base improvements, and we shall doubtless hear of its gradual elimination. A modification is the rising and falling shed with stationary bottom (fig. 254, 4).

Open Shed.—As the term implies, the heald shafts of this system are hung so as to preserve an open shed (fig. 254, 3 and 5). When a warp thread changes position, it passes from the one extremity to the other at a single stroke. In cases where no change in the warp is required by the pattern, the threads unchanged remain in position. This effects a saving of movement in a very large number of patterns. Having been adjusted to the open shed, the warp is not strained by the shedding. Making all the changes at one stroke, the open-shed healds save time. Open shed is most suitable for swift looms and tender yarns. Some few defects are inherent in the open shed, however, and should be noted carefully. To maintain an equal tension upon all the threads of the warp in open shedding is difficult. On two pairs of shafts the tension practically regulates itself; but when we attempt to work, say, 24 to 36 shafts, the difficulty becomes very serious. The back shafts of the series can hardly be prevented from bearing heavily on the warp, causing breakages. Moreover, when such breaks do occur, they are not easily mended. To effect a join, the healds should be brought level, all the mails on the same plane. Having made the join, the next problem is the readjustment of the warp—a very delicate and difficult piece of work.

Semi-open Shed.—The double-lift Jacquard forms what may be called a semi-open shed, which combines the stationary bottom with the open shed. Though very simple in action, this method is rather difficult to understand from a description. As a matter of fact, we must, in order to obtain clearness, suppose that the stationary bottom warp is equal to the bottom warp of the open shed, and that the section of warp threads which are to be raised at the pick following, though depressed at the moment, represent the centre of the closed shed; the elevated section of the warp is, of course, the height of the ordinary lifted warp (fig. 254, 6). A considerable amount of time and friction is saved by

this method—at least it is an improvement on the closed shed with a stationary bottom. Many well-known shedding motions form the shed on the semi-open plan.

Warp-shedding Systems.—Among the many warp-shedding appliances, and the numerous minor details of each, it would be possible to wander confusedly. The Patent Office contains hundreds of patents, and in the factories throughout the country there are thousands more; but the vast mass can be grouped into four clearly defined systems, and by selecting types of each we can gain a clear view of the principles upon which all the main varieties of warp-shedding appliances have been based. The systems are:—

1. The Tappet System.
2. The Dobby.
3. The Jacquard.
4. Gauze, Pile Warp, and Fancy Weaves.

The Tappet System.—Sometimes readers of textile manuals, and enquirers into the subject generally, find themselves confused by the careless manner in which technical terms are employed. Here we have a good instance. "Tappet, cam, and wiper", says a writer, "are names given indiscriminately to those irregular pieces of mechanism to which a rotary motion is given for the purpose of producing, by gliding contact, reciprocating motions in rods and levers. When the rod is to receive a series of lifts, with intervals of rest, the piece is generally called a tappet; but if the motion is continuous, the terms cam and wiper are used."

We hardly think the definitions given will altogether correct the tendency of workers, and even writers of textbooks, to employ the terms as fancy dictates; but the writer has described with fair accuracy the mechanism itself and the original applications of the three words.

A Simple Tappet and Gearing.—In the power loom the tappet performs the function of the weaver's foot in the hand loom. Nothing could more clearly illustrate the fact that the former was a mere imitation of the latter. The heald shafts are hung in precisely the same fashion, depending from a roller hung from the head of the loom frame. To the bottom shafts of the heddles the treadles are attached. One difference, however, occurs; instead of the treadles coming out to the front of the loom, they extend to the back, and there are fulcrumed on a fixed pin. In this guise the treadles take on their proper shape of levers. Another addition should also be noted. On the upper sides of

the treadles, fixed in a grooved notch, are solid little rollers or bowls. Upon these work the tappets or cams (fig. 255).

Without scanning too closely the shape of those tappets, we should say that they are somewhat like pulleys badly shaped and inserted at a strange angle. The tappets are firmly screwed on to a shaft traversing the loom frame horizontally. A toothed wheel on the end of the shaft fits into the pinions of the main shaft, driving the batten and slay. When the loom is set going, therefore, this shaft turns round with the crank shaft in a given proportion of revolutions. Coming more closely up to the tappets, we observe that the distance from one side to the driving shaft is little more than $1\frac{1}{4}$ in., while the distance between the shaft and the widest part of the tappet is about 4 in. The treadle bowl is always in close contact with the tappet, and it follows therefore, that, when the longer side comes round upon it, the treadle will be depressed. If the shortest part has only contact, and no more,

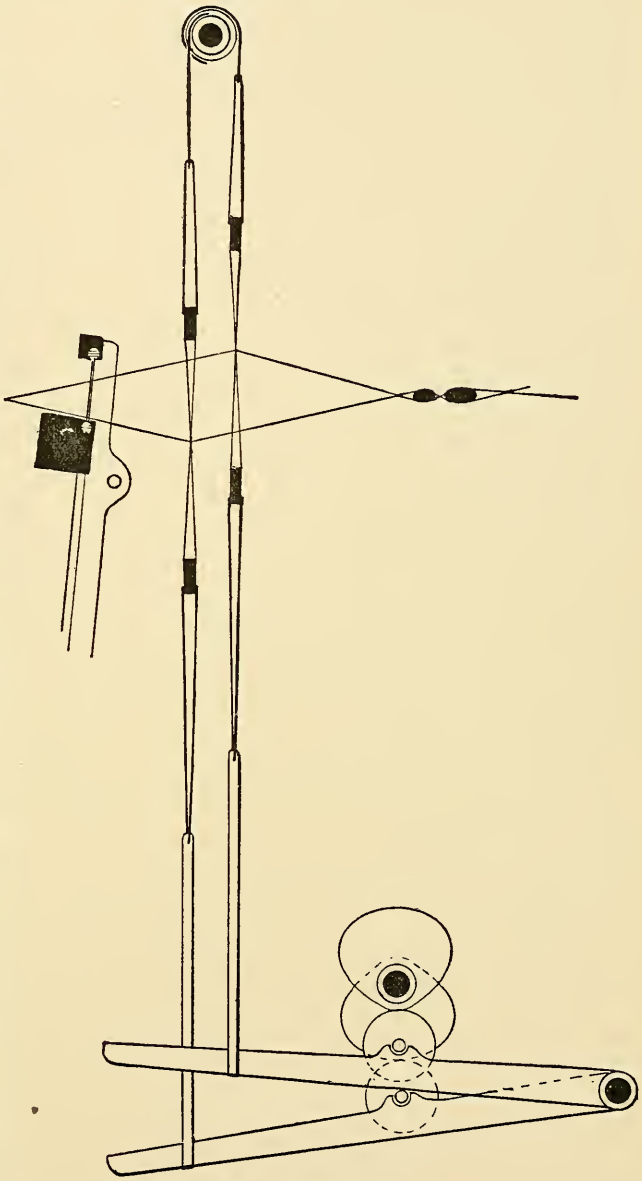


Fig. 255.—Simple Tappet

the treadle will be up when it lies against that section. In this we have the up-and-down motion of the treadle secured. The short side of the tappet, at least, does not depress the treadle, while the long side does. Given that the two eccentric cams we call tappets are fixed on the shaft so that the short sides oppose each other, and that a tappet works on each heald treadle, we find that when the one treadle has been depressed the other is up. The depression of the treadle pulls down the heald shaft to which it is attached, and the warp with it, forming a shed.

Another Tappet of Simple Character.—Before going on to study the tappets and their gearings more minutely, let us look at another form of gearing. If we learn that the same effect is produced by a different shape of apparatus, we shall know that the differences which occur are not attributable to the gearing.

The treadles extend to the front of the loom and rest in a fixed fulcrum; upon the upper sides of the treadles the bowls are fixed as above; and the position of the tappets is the same (fig. 256). But from the ends of the treadles long cords or rods extend up to a pair of short levers, named *jacks*, gripping on to the ends of square shafts. Upon each square shaft a pair of half-moon levers is mounted, and over the arc of each half-moon lever a strap, fastened to its base, depends. Cords connect the pair of straps on the same square shaft with the heald shaft of the heddle proper to it. Reviewing the whole mechanism, we observe that each heddle has a treadle, tappet, long rod, jack lever, square shaft, and pair of half-moon levers, with straps and cords. For the sake of simplicity, a mounting of only one pair of heald shafts is given, but we might as easily have a dozen. It is merely a question of how many additional treadles, streamer rods, jack levers, square shafts, half-moon levers, and other accessories the loom will carry and work profitably. The parts of the apparatus admit of a considerable range of adjustment. Being perforated with a number of holes, the treadles can be shortened; the jack levers are toothed for a similar end; the half-moon levers can be moved to any position upon the square shafts. By these helps the weaver is enabled to get as many as twelve heald shafts on to the loom.

Turning again to the simple example, with only two tappets operating two heald shafts, we follow this *modus operandi*. Tappet No. 1 turns on the shaft and brings the heavy side of the tappet to bear on the bowl of treadle No. 1, depressing it. The depressed treadle pulls down streamer rod No. 1, acting on the jack 1, and through it on

square shaft 1, causing the half-moon lever to draw up heald shaft No 1. Though the train seems somewhat long, it acts easily, and consumes little power. Heald shaft No. 2 is operated by tappet No. 2, and so on.

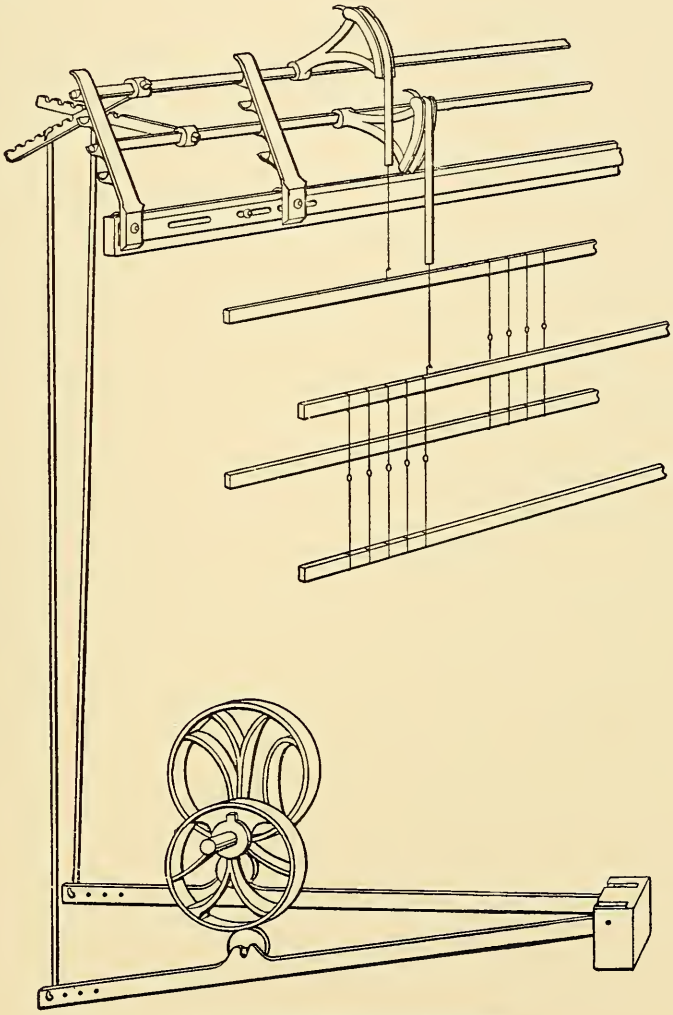


Fig. 256.—Shedding Motion of Tappet Loom

Over and Under Motions.—Neither of the shedding appliances which we have examined possesses the means of reversing the action of the tappets on the heald shafts. *Negative tappets*, as they are called, they represent a very large class. In the one case, the heddles are depressed, and in the other, lifted; but neither seems to have the power of reversing the action.

Examining the very simple tappet apparatus again, we find that the pair of heddles are hung upon a roller suspended from the head frame of the loom. A pair of straps hold each shaft to the roller; these straps are nailed to the roller in such a way that, as the heald shaft is depressed the strap unwinds, and winds on when the shaft is elevated. The pair of heddles, therefore, act upon each other. As the one is depressed, and unwinds the straps from the roller, it causes the straps on the opposite side of the roller to be wound on, thus drawing up the heald shaft attached. Suitable for hand-loom weaving and the slower of the plain power looms, this method lacks the steadiness and accuracy demanded by the workers in the great factories. It contains the root idea, however, and must be counted more efficient than some of the very complex and pretentious appliances which have been offered to weavers in the name of improvement.

Instead of trying to develop reversing motions on the principle above described, loom mechanics have sought an easy way out of the difficulty by resorting to springs and weights. The last refuge of the baffled mechanic is a spring; if he cannot obtain power by any other means, he devises some form of spring. In their proper function, as aids, buffers, cushions, or mechanisms to which leverage or power cannot be applied, springs perform immense service; but no instrument has been more often misapplied. Take the case of a set of springs as under motions for reversing the action of the lifting tappets. A spring is attached to each end of every heald shaft. To hold the shaft in position, the spring must be stretched, exerting force sufficient to keep the heald shaft in position (fig. 257, *a* and *b*). In his book on *The Mechanism of Weaving* Professor Fox lucidly explains the action of springs as reversing tappet motions.

"As usually applied, a spiral spring is one of the most defective pieces of mechanism that could be devised to reverse movement in healds. A spring must be stretched until it exerts sufficient force to hold its heald on the top or bottom line when the tappet is inoperative; and therefore the further the heald moves from that position, the more a spring is stretched, and the greater the force it exerts to oppose that of the tappet. On the latter ceasing to act, the spring exerts its maximum force to pull the heald shaft in the opposite direction, and this takes place when the least force is needed; the spring then contracts, and its force decreases in proportion to that of its increase when stretched, until the place is reached where its effectiveness is needed, and there it exerts its minimum of force. The spring is therefore strongest where it should be weakest,

and weakest where strength is most required. A comparison of the power consumed by springs and dead weights will make this point clear. Let it be assumed that a force equal to 10 lb. is needed to hold a heald shaft stationary, then a spiral spring must be stretched until it is capable of resisting that force. Let it be further assumed that such stretch = 1 in., and the movement of the heald = 4 in. Since the force of the spring increases uniformly, 10 × 5 = 50 lb., the force

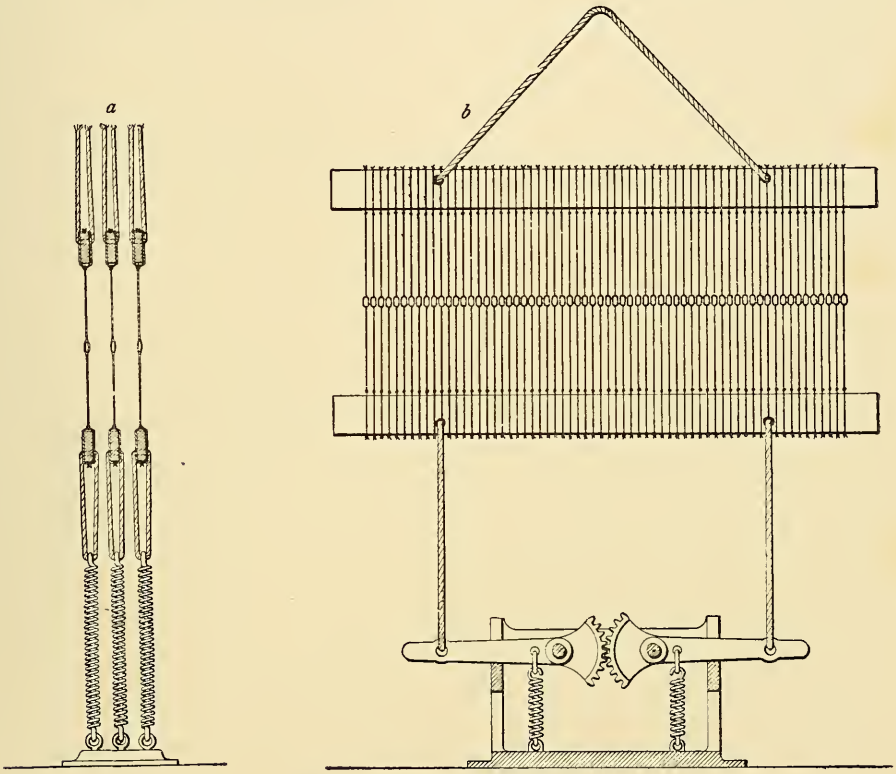


Fig. 257.—Spring Reversing Motions

exerted when it is not wanted, and 10 lb. its effective force. Or, put into units of inch pounds, 50 ÷ 2 = 25 lb., the mean power, and 25 × 5 = 125 inch pounds."

Because handy and simple in construction, demanding no mechanical skill, the spring remains in constant use on light looms almost everywhere. Weavers and manufacturers are no doubt aware of the objections which are urged against the practice; but other choice is not at all times open to them. If the springs are always kept in good condition, and the least possible weight put against the tappets in

working, the essential defects of the springs may be reduced to very slight consequence.

Kenyon's Under Motion.—It is possible by the employment of levers to reduce the pressure of the springs upon the tappets. A very popular appliance of this kind is Kenyon's under motion (fig. 258). This apparatus has for its centre a spiral spring, the action of which is greatly modified by attached levers. At each end of a rail under the loom a chair is firmly bolted, the back of the one opposed to the back of the other. Upon the head of each chair a strong and curved lever is fulcrumed; on the extremity of each lever the cord controlling the heald shaft is linked. The levers are movable, but they are braced at the fulcrum by strong ratchet pins. Between the two chairs, and terminated by fine chains, is stretched the long spiral spring. When

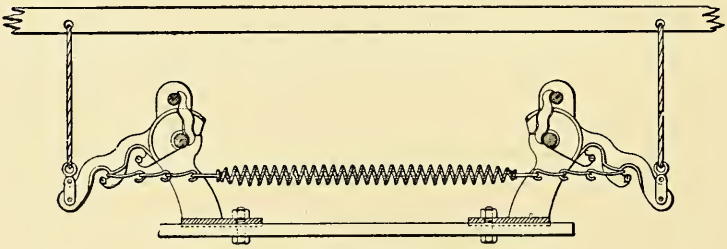


Fig. 258.—Kenyon's Under Motion

the heald shaft is lifted it draws up the two linked levers, and at the same time stretches the spiral spring. But by degrees the pressure of the spring is transferred from the heald shaft to the curved levers; at the horizontal point the spring is really stretched between the levers. If the lift of the heald shaft has been made equal to the curve of the levers, the last pressure of the tappet is practically free. When the heald shaft is released, the reversing action is limited to the force exerted by the spring after the levers have passed below the horizontal level, or even less. The chairs are made movable on the rail, so that when the spring slackens slightly, through wear, the stretch may be increased to the distance required.

Hahlo, Liebreich, & Hanson's Patent.—A more complex, but equally efficient, apparatus is Messrs. Hahlo, Liebreich, & Hanson's patent reversing motion (fig. 259). Within a rectangular frame a series of simple appliances are combined. In the head of the frame is the fulcrum base of a pair of levers reaching out under the heald shafts, or over them, as the case may be—for this is employed as an

over motion when necessary. Both levers are slotted to carry straps of whatever length the weaver requires, and notched for the heald-shaft straps. An arm shaped like an arc comes out from the frame to support and guide the motions of the levers. At the base of the frame we find two eccentric cams or pulleys, closely resembling round tappets in shape and action. To the base of each lever, at the fulcrum end, a spiral spring is attached. From the end of each spring a belt runs round one of the eccentric cams, and the end is fastened in the outstretched arm of a lever. When the one lever is lifted it draws the cam round, and the latter yields up a small length of the strap wound upon it. The pull of the strap stretches the spiral spring, of course, but not of the length which might at first sight appear necessary. The end of the spiral spring is attached to the extremity of the lever, which is lowered as the other end is lifted, and therefore the tension is relieved to that degree. Through this combination of devices a heald lift of 5 in. only acts upon the spiral spring to the length of $\frac{3}{4}$ in. Taking Mr. Fox's data, and allowing 10 lb. for the normal pressure of the springs, we have a total pressure of $17\frac{1}{2}$ lb. for the lift of the heald shafts. Being strongly and simply constructed, this reversing appliance is easily worked and seldom gets out of order.

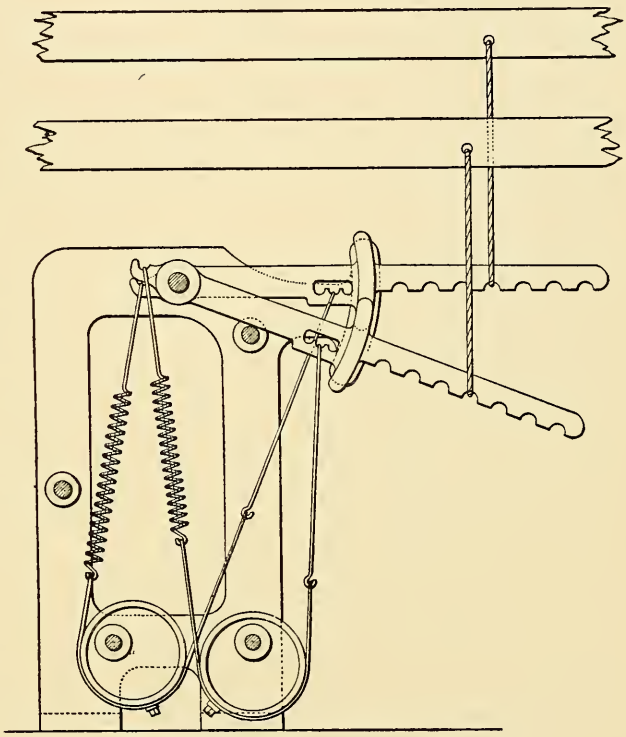


Fig. 259.—Hahlo, Liebreich, & Hanson's Reversing Motion

Stocks and Bowls.—There are many other spring reversing motions in use, some patented, and many simply applied in the factories where they were invented. We have elected to detail those mentioned, for

study purposes merely, and because they seem to contain the leading principles to be found in all appliances of the kind, not for the purpose of recommending them above others. Exhibiting a mechanical talent and resource much superior are those appliances which employ no springs. The leading idea in the best appliances consists in an arrangement of stocks and bowls. Let us try to exhibit a specimen of the under motion in this style (fig. 260). Two stout levers are fixed under the loom, one at each side, and balanced on a fulcrum so that the levers may have full play. Four heald shafts are to be worked by this particular example, though more can easily be added, as we shall see. Upon each end of the lever a pulley is fixed; round each pulley a strap is passed. Strap No. 1 is connected with heald shafts Nos. 1 and 4; strap No. 2, on the other pulley, is connected with heald shafts Nos. 2 and 3. By this combination of levers and pulleys four heald shafts can be operated, so long as we suppose that one out of the lot is depressed at any one time. Say, for example, shafts 1, 2, and 3 are lifted, and 4 depressed, then the lever would be depressed at end No. 1 and elevated at end No. 2; at the same time the strap on pulley 1 would lift for heald shaft 1 and decline for shaft 4. The lift of the lever at the one end and the draw of the strap at the other amply suffices for the lift of the heald shafts involved. Next, suppose an opposite case: shafts 1, 3, and 4 are lifted, and 2 is depressed, then the lever would be depressed at end No. 2 and elevated at end No. 1, while strap No. 2 would be required to yield enough to let heald shaft 3 rise; this would effectually depress shaft No. 2, because both the end of the lever and the pull of the strap would be against it. It seems hardly necessary to exhaust the example. If shafts 2, 3, and 4 are lifted and 1 is depressed, end No. 2 of the lever would rise and end No. 1 decline, letting shafts 2 and 3 be lifted together, while shaft 4 would be allowed to lift by the giving out of the strap on pulley 1, and shaft No. 1 would be depressed by the same cause. In the fourth instance, shaft No. 3 would be down and shafts 1, 2, and 4 lifted; to accomplish this, the lever would be depressed at the side holding the pulley over which the strap controlling heald shaft 3 is run; the one end of the strap, which is attached to shaft 2, would be let out, and therefore shortened for shaft 3, the depression of the

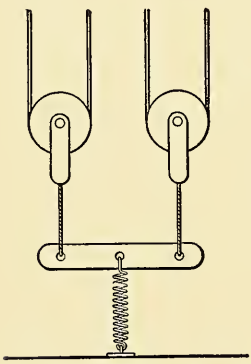


Fig. 260.—Stocks and Bowls

lever and the shortening of the strap combined depressing heald shaft 3.

Extended Application of Lever Principle. — A contrivance so suitable and inexpensive could hardly fail to acquire a hold on the weaving trade, and extensions of its usefulness are to be expected. Fortunately, once the principle has been understood, very wide extensions are easily possible. For instance, by adding on two pulleys to each end of the four-shaft lever, above the pulleys already upon it, we obtain a six-shaft reversing motion (fig. 261). One end of the strap on the two original pulleys is nailed to the framing of the two new pulleys at each end of the lever; then straps are fastened to the new pairs of pulleys themselves. That is to say, each strap of the base pulleys operates one heald shaft and a pair of pulleys. It is necessary to note, however, that the diameter of the bowl controlling two shafts is in inverse proportion to the shaft controlling one. This rule practically involves the conversion of the base pulleys into two divisions, changing them from simple to compound pulleys. The pulley is in two sections, the one controlling two shafts being half the diameter of the part controlling one. Any five of these heald shafts can be lifted at once and one depressed; alternatively, any one of them can be lifted while all the others are put down. The weaver is thus enabled to utilize all his heald shafts, with the certainty of being able to reverse whatever motion he has given them. Suppose, for example, we desire that shaft 1 should be depressed, and shafts 2, 3, 4, 5, 6 lifted. That end of the lever to which shaft 1 is attached would be depressed; the strap on the block of the pulleys controlling shafts 4 and 6 would be let out, drawing down shaft 1 still farther; the side of the lever holding the pulleys of 2, 3, and 5 shafts is elevated by the depression of the other end, and these shafts are therefore lifted without movement of the straps. All the variations possible upon a six-heald weave can be practised upon this system, the couplings of the straps and the motions of the levers performing all the work.

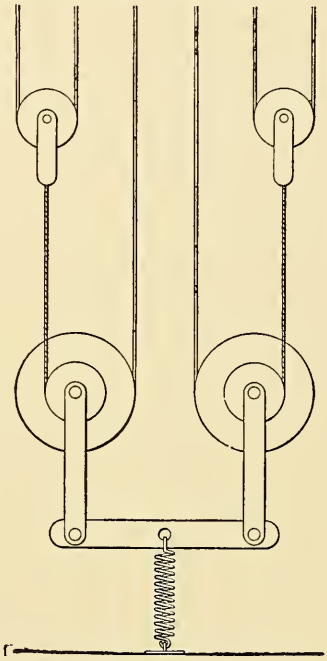


Fig. 261.—Stocks and Bowls for Six Shafts

Sometimes we are required to weave with five, seven, nine, eleven, or any odd number of shafts, and the difficulty at first seems rather formidable. We observed, however, that the fulcrum pin of the lever controlling an even number of shafts is in the centre. The lever is divided up into equal sections along its whole length. In this case we suppose it divided into six equal sections, three on each side for an even number of healds. For a five-shaft weave we would have to divide the lever into five sections, and place it in such a position that three-fifths of its length would be on one side of the fulcrum and two-fifths on the other (fig. 262). The end of the lever controlling the three shafts would be the shorter, and the end controlling two shafts the longer. The greater weight of the four heald shafts would thus be compensated for by the shorter lever.

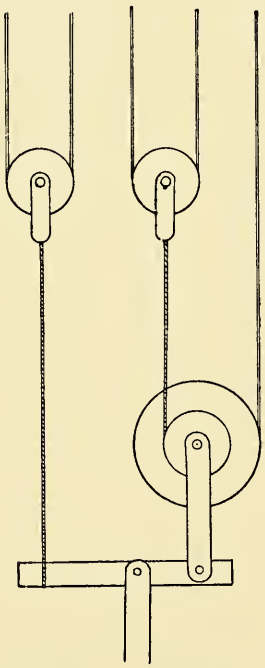


Fig. 262.—Stocks and Bowls for Five Shafts

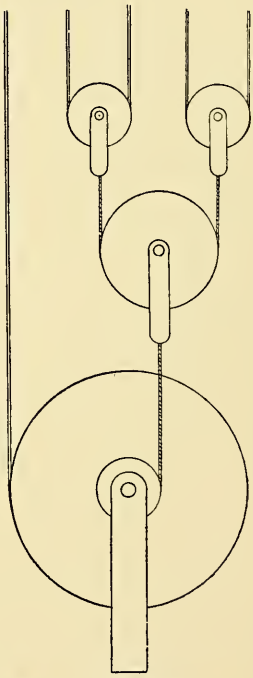


Fig. 263.—Another Example of Unequal Shafts

The variations upon these reversing motions are worked out in many ways, on appliances of various shapes and sizes (fig. 263). A favourite method is to make the fulcrum of the lever a spring; the spring imparts elasticity and mobility to the apparatus; a wide range of heald shafts is controlled by the spring-levered appliances.

Formation of Tappets.—The centre of the tappet mechanism is, naturally, the tappet. Up to this point we have treated of it as a simple cam, the function of which is to depress or lift the heald shafts. Closer acquaintance, however, altogether dispels the idea of simplicity, and the discovery is made that even the tappets of a plain weave are far from simple in structure and function. It is possible to approach the tappet from several sides, all correlated with other parts of the loom. First, and most important, the shape of the tappet claims

attention. One tappet imparts to one heald shaft all its positive motions. The rule is that one revolution of the tappet represents one complete series of changes in the motions of the heald shaft it actuates. Taken together, a set of heddles and their tappets embody a complete pattern. Second, the speed of the tappets relative to the mechanism of the loom is a vital factor in weaving. Changes in heddle movement imply picks of weft and beating up; the number of picks, therefore, to each revolution of the tappet determines its relative speed. If there are four treadle changes in the tappet revolution, it turns once for every four turns of the main crank shaft; if there are twenty, the proportion is the same. Thirdly, the required size of the tappet has to be accurately ascertained. Into this problem a number of factors enter: Number of heald-shaft changes and their distribution, size of shuttle, the length and depth of shed, leverage of mechanism, and cognate matters. Having in mind the immense variety of patterns and weaves in textile manufacture, the different sizes and kinds of looms, and the wide range of fibres, enquiry into the shape, size, and speed of all the tappets employed would seem to involve an almost endless labour. Fortunately, however, each particular is governed by a single principle. If we find the method of shaping one tappet, we have discovered how to make all shapes of tappet; when the relative speed of the tappet to the slay crank, or main shaft, has been determined in one case, the principle can be applied to all cases; similarly, the relation of the size of one tappet to its position and function having been found, it can be made the rule for fixing the sizes of tappets generally. Exceptions do occur, and preferences vary; but, having grasped the three principles at the basis of all power-loom shedding, the weaver has no difficulty in discounting deviations from common rule.

Shaping the Tappet.—Though agreed upon the main principles, makers and designers of tappets, weavers, and technical instructors differ seriously in their methods of determining the shapes of the tappets and details of the structure. Several causes account for this apparent discrepancy, where, it would seem, there could not be any deviation. The chief cause is the relation between the tappet and the treadle bowl on the one side and the stroke of the picker on the other. For example, some weavers allow a pause of the heald shafts equal to one-third of the pick at every shedding; others allow for a pause of one-half of a pick. This means that the treadle bowl, in the first instance, is given an equal surface of one-third the changing

surface of the tappet to travel upon, so that no change may take place in the movement of the healds during that time. In the second instance, the tappet is evenly divided between what is called the *dwell* and the change. Again, it is possible to vary the size of the treadle bowl from 1½ in. in diameter to 3 in. or more.

Being an eccentric cam, the tappet must be shaped according to the lines it is intended to describe. Though a circle, it should be clearly understood that the motions of the tappet can be described by a horizontal line; upon the heald shafts, indeed, the motion is actually an up-and-down traverse upon a horizontal plane. Suppose that, in making a tappet, we were precluded from dealing directly with the cam, and required to draw a plan from the motions of the heald shaft; how would we proceed? A tappet for plain weaving gives two picks to the round; that, expressed in a horizontal figure, would mean two sharp angles, drawn down from the straight line. The bases of those angles must be equal. But between each two angles there must be a space to represent the interval between the one stroke of the heald shaft and the other. Let the line upon which the figure is based be divided into three, one to represent the interval and the other two spaces the bases of the triangles. The width of the triangle base determines the degree of the angles. Suppose, therefore, we choose to make the interval one-half the total figure, the shape of the triangles would be changed materially. From an angle of, say, 90 degrees, the sides of the triangles would be changed to an angle of 45 degrees.

We have pursued this theoretical argument far enough to show the point; if the proportions of the tappet are altered, its shape is altered also; the same happens when the co-relative of the tappet is changed in size or proportion. The effect of this twofold principle is far-reaching. Tappets for plain weaves may be different in shape, we see. That tappets designed for complex weaves differ from plain tappets is accepted as a self-evident fact; but it is not always understood that the principle which may vary the shapes of plain tappets is the principle which determines the different shapes of all kinds of tappets. Apart from a clear understanding of this fundamental fact the subject of tappet designing is a very confusing tangle. Working upon the mathematical principle just indicated, it is open to anyone to design any form of tappet required for any conceivable weave.

Practical Tappet Design.—The tappet acts upon the treadle bowl, and through it upon the treadle; upon the degree of pressure put

on the treadle bowl depend the motions of the heald shaft. The distance of the centre of the bowl from the axle of the tappet is the measure of the depression of the treadle. As we have already hinted, there are other factors, but these must be regarded as constant quantities, and need not be considered meanwhile. First, then, we fix two points, the one to stand for the centre of the treadle bowl and the other for the centre of the axle of the tappet, when both are at their point of nearest approximation. That is to say, the points mark the centres of tappet and bowl when the bowl is touching the smallest part of the tappet. Upon these points describe a circle, the centre of the tappet being the centre of the circle. So far as this circle is concerned, the size of the space matters nothing. It may be 2 in. or 5 in.; the important thing is that the radius of this circle exactly corresponds with the distance from the two centres mentioned. But the next step involves actual measurement of a particular cam or tappet. For a rigid rule, we here require to substitute a principle which may be variously applied. The point now to be arrived at is the size of the tappet, and that depends wholly upon the size of the lift which the tappet is to impart to the heald shaft. Say that the lift of the cam is to be 3 in., then the larger side of the tappet must be 3 in. farther from the centre of the treadle bowl than the shorter side. Extend the radial line from the centre to the circumference of the circle drawn by 3 in., and describe upon the whole line a circle.

These two circles contain the whole area upon which the treadle bowl works, the centre of the bowl never coming closer than the circumference of the smaller circle, and never going farther away than the circumference of the larger circle. From this point we might begin to design any form of tappet; those circles are the ground plan of all tappets. The simplest is the plain-weave tappet, which most clearly illustrates the method of the whole operation. We derive two picks, or two heald-shaft motions, from the whole of the plain tappet, one from each side. To allow the shuttle time to pass through the shed of the warp, we try to secure a pause between the lift and the depression of the heald shaft. The motion of the tappet cannot be stopped; but the change in the movement of the treadle bowl can be delayed by the form of the tappet. Practical men advise two different methods of determining the measure of the dwell, and the consequent form of the rest of the tappet. Let us take the simpler first. Draw a straight line through the centre of both circles, cutting them in halves. Divide each semicircle into three equal parts; the small

circle and the large circle are thus parted into thirds. The third of the large circle must be taken as the measure of the dwell on the lift of the tappet, and that on the small circle as the measure of the dwell on the depressed heald shaft. But the question now remains: How can the space between the small and large circles be bridged over? It is necessary to secure a graduated motion of the treadle bowl upon the tappet. Draw five radial lines at equal distances from each other in the spaces of the middle division of each semicircle, from the centre to the circumference; upon these radials describe six arcs at equal distances from each other, within the space between the small and the large circles, forming upon the radials a series of parallelograms. Draw from corner to corner of the first parallelogram a curved line; this line terminates at the outer corner of the second, and we extend the line in the same direction, curving into the corner opposite. Similarly, parallelograms 3, 4, 5, and 6 are cut, the whole line terminating on the circumference of the small inner circle, which was the aim of the whole plan. Performing the same operation on the other semicircle, we obtain a complete figure.

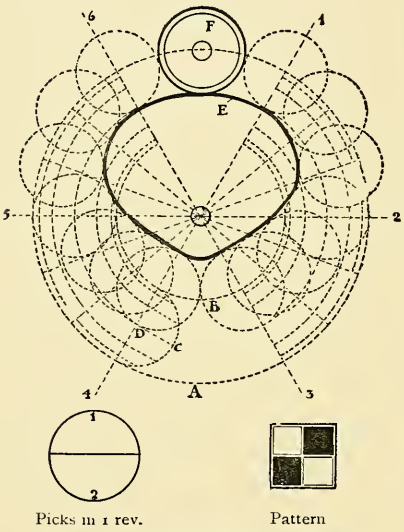


Fig. 264.—Draft for Plain Cloth Tappet

F, Bowl of tappet lever. E, Shape of tappet. B, Circle on radius from tappet centre to bowl centre at shortest distance. A, Circle on radius from tappet centre to bowl centre at highest point of lift. C, Middle circle. D, Point of intersection. 1, 2, 3, 4, 5, 6, Radial lines dividing the circle.

The figure drawn represents only the line of the movement of the centre of the treadle bowl. To reduce it to proper shape and dimensions, a regular series of arcs equal to the half of the treadle-bowl circumference must be drawn intersecting. Upon the tangents of these arcs a line is drawn, giving the exact outline of the tappet required.

The second method is perhaps the more scientific (fig. 264). Divide the two circles into equal parts. Subdivide each semicircle into three, and name the radials thus made 1, 2, 3, 4, 5, 6. The space between 1 and 3 equals two-thirds of a pick, and the space from 3 to 4 equals one-third of a pick. Also, the spaces 4 to 6 and 6 to 1, are equal to two-thirds and one-third of a pick respectively. This gives the two picks and the accompanying dwells. Now divide the spaces 1

to 3 and 4 to 6 by radial lines into six parts each. Inscribe a semicircle upon one of the radial lines, equal in diameter to the space between the two circles and touching both. Divide the periphery of the semicircle into equal parts, corresponding in number to the radials already noted in each of the divisions 1 to 3, and 4 to 6. From each point of intersection on the periphery of the semicircle, connecting the two circles outer and inner, drop a line perpendicular to the diameter line, thus obtaining the inequality necessary for our

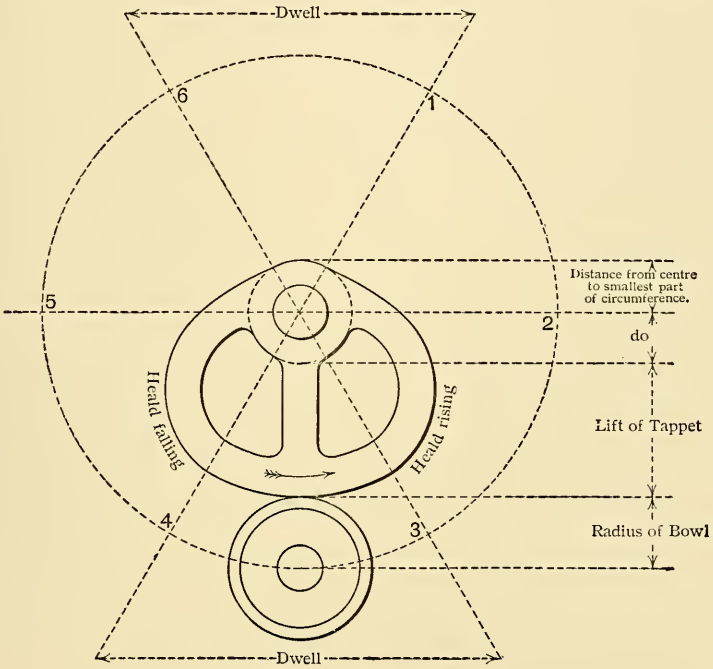


Fig. 265.—Completed Tappet

main purpose, viz. inequality of curve upon the tappet. Through each point on the diameter line describe a circle concentric with the inner and outer circles aforesaid. Each point where a radial line is cut by a curved one represents the centre of the treadle bowl at one part of the lift. Taking these points for centres, describe a series of circles equal in diameter to the bowl of the treadle. Convert the tangents of the circles into joined lines, and the outline of the tappet required will appear. Upon the third of both the large and the small sides of this figure describe a clear arc, so that the dwell of the treadle bowl may be smooth and steady. The completed tappet (fig. 265) shows all the factors operating in forming the shape of a plain tappet.

Deviations in Shapes of Plain Tappets.—As a rule a set of tappets consists of so many duplicate plates or cams; but certain conditions cause differences which must be taken into account. For instance, on the plain tappet most commonly used, in which, the heald shafts being mutually dependent, the pair of treadles work at different angles. The one heald shaft hangs in front of the other, and therefore the angle at which the treadle bowl works must be shorter on the former than on the latter. If no steps were taken to correct the discrepancy, every alternate shed would be either too wide or too small. Jerky movement and broken warp threads are commonly the result of the error. A practical method of arriving at the second tappet shape and dimensions is to put the first cam to both heald shafts, and mark the difference between the two on the small and large sides; add on that difference to the size of the cam or tappet.

Long-continued strain and sudden jerky change upon warps are almost equally injurious, and the problem the tappet designer has to solve is to find the happy mean. In the common shape of plain tappet just shown, the motions are gradual, the cam being specially graded from one point to another; but the long rise and fall does not always suit. For tender warps a sharp change is still more dangerous. To meet the difficulty, the sides of the tappets between the lifting point and the lowest are given a concave form, carrying the tappet swiftly away from the lifting point, but arresting it as it approaches the small side.

In fixing the cams, care must be taken to turn them towards each other at an angle of 180 degrees. That is, each tappet stands to the other in the same position as two halves of a circle.

Tappets for Twills and Checks.—So far we have only considered the application of tappets to plain weaving; but those cams are occasionally employed in weaving very elaborate patterns, containing as many as twenty-four picks and using as many heald shafts. There are reasons why other appliances are better suited for such patterns, but the difficulty does not lie with tappet structure. On the first thought, one would imagine that the contrary would be the case, and that a tappet changing the motion of a heald shaft twenty-four times would be an impossible shape. Let us be quite clear. In shaping a tappet we do not need to concern ourselves with the number of healds which may be required to carry through a particular pattern; each tappet operates one heald shaft only, and the shape of it depends wholly upon the number and succession of picks of the pattern in

which the heald shaft takes part. Both tappets and healds are mutually related, of course, but that side of the matter should be left out of sight for the moment.

Suppose a set of tappets for a three-end twill is required. In a single revolution the tappet shaft must complete the pattern. Each tappet has three motions. Therefore the circles for the large and the small sides of the tappet must be divided into three, instead of the two of the plain-weave tappet. Each third of the circles is treated in precisely the same fashion as the halves of the circles described. The same procedure is followed (fig. 266). For the small circle draw a line equal in length to the distance between the centre of the tappet and the centre of the treadle bowl when it is upon the smaller side of the tappet. Add to the radius drawn the length of the tappet lift, and describe upon it the larger circle. While the tappet revolves once, and the shuttle puts in three picks of weft, the heald shaft performs three motions. Therefore the figure is divided into three equal parts, and each part treated in the same manner as the halves of the circles drawn for the figure of the plain tappet.

By following out the directions given, and drawing line after line as directed, the student will find himself in possession of the shape required, without deliberate plan on his part, it may be, but simply from the effect of the lines drawn. The four-pick tappet (fig. 267) is simply another example. Something more is needed when tappets for pattern weaves are to be designed. The principle is

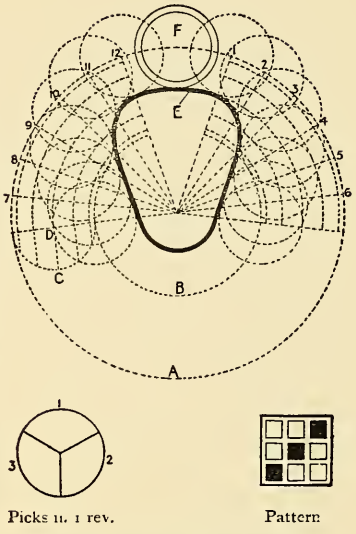


Fig. 266.—Draft for Three-pick Tappet

F, Bowl of tappet lever. E, Shape of Tappet. B, Circle on radius from tappet centre to bowl centre at shortest distance. A, Circle on radius from tappet centre to bowl centre at highest point of lift. C, Middle circle. D, Point of intersection. 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, Radial lines dividing the circle.

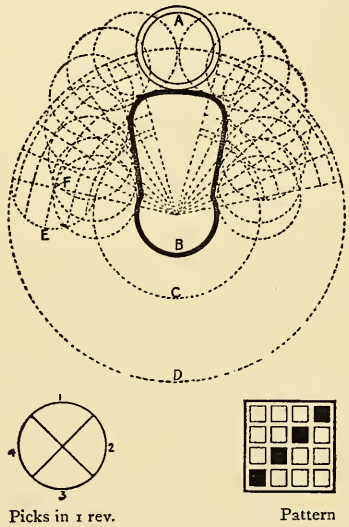


Fig. 267.—Draft for Four-pick Tappet

A, Bowl of tappet lever. B, Shape of tappet. C, Circle on radius from tappet centre to bowl centre at shortest distance. D, Circle on radius from tappet centre to bowl centre at highest point of lift. E, Middle circle. F, Point of intersection.

identical, but the application must be planned. In some patterns the heald shaft may be elevated one pick and depressed for two or three, and many obvious variations are possible. Before making the tappet, therefore, the worker must study the weave in all its details, and find the number and succession of heald-shaft motions in the pattern and the exact motions of each heald shaft. Say that we have to work with eight shafts, with eight picks, giving a twilled effect. Analysing the weaving we find that shaft 1 is lifted at pick 1, depressed at pick 2, elevated at picks 3, 4, 5, and depressed at picks 6, 7, 8; this gives one tappet. To shape the tappet required, the two circles which we have already shown to form the foundation of all tappet figures are divided into eight; then each of the eight sections is treated as representing a single pick, and the shape of it determined by the same rules as determine one of the two picks of a plain tappet. After every pick has been independently shaped it will be found that the whole tappet is of the form required. Most of the difficulty of understanding the construction of tappets arises from two causes: First, the rudiments of the process hardly require explaining in the workshop or in the designing room, where everybody sees the materials, and some abbreviations of the operation are practised without being defined. Second, the combination of the whole tappet and set of tappets in one view tends to give an appearance of complexity to a simple succession of simple operations.

Returning to our analysis, we note that heald shaft 2 is down at pick 1, up at pick 2, down at pick 3, and up at 4, 5, 6, but down at picks 7 and 8. It will be observed that this succession of motions does not change the shape of the tappet from the first; the only thing needed would be to screw the second tappet on to the shaft so that the first projection of tappet 2 would come into line with the opening at 2 of tappet 1. The other six tappets obey the same rule, producing an eight-shaft twill of a very neat and popular pattern.

In a thousand patterns and more each heald shaft acts in a different way from every other to make the pattern, either in time of motion or succession of motions. For very complex patterns it is generally considered more economical to employ one or other of the patent tappet arrangements which have been invented to facilitate the working of tappet patterns. No insurmountable difficulty exists, however, in the way of anyone who chooses to work out the tappet designs for himself. The whole operation involves nothing more than careful observation of the rules prescribed.

Patent and Positive Tappets.—As soon as we leave the commoner forms of tappet, we enter into a region in which there is constant difference—a progression from the merely specialized form of tappet to the mechanisms which are tappets in nothing more than the name. Based upon a mechanical principle which is the common property of all mankind, tappets of the cam shape cannot be made the subject of a patent. It is open to every weaver to make his own cams for every kind of weave imaginable; but ingenious mechanics have devised and patented tappet appliances of great service to the trade. First, the inventors took hold of the negative tappet, and sought to make a firmer connection between the driving shaft and the heald shafts than the cords and tappet-driven treadles afford. The time and trouble involved in the setting of the tappets suggested a permanent basis upon which any form of tappet plate might be set. Simultaneously, the development of the positive tappet took place. At first the positive tappet was nothing more than a cam with a rim to enclose the treadle bowl; but the mechanical impulse imparted to the heald shafts by the positive action brought other forces into play. The question arose: Why should we depend upon the tappet form at all? The lift and depression of the heald shafts is only a form of lever motion after all, and it is surely possible to devise means of accomplishing the operation simply. From this idea sprang mechanical tappets which are different totally in make and action from those described. In process of time the purely mechanical and automatic method of heald manipulation may be more largely employed than the older tappet method; but that occasion has not yet arrived, partly because the newer mechanisms have not been so thoroughly perfected as to leave no doubt of their superiority, and partly because of the wise conservatism which governs the industry. For it must not be inferred that the tappet, and all the science of tappet structure, is necessarily to be superseded and rendered obsolete. After the mechanics have done their best, the tappet will remain the standard upon which power-loom shedding must be based.

A Patent Tappet.—One of the earliest and most typical of the patent tappets is the "Jamieson" (fig. 268). The base of the tappet plates is a spur wheel connected with the driving shaft, in which as many holes are drilled as there are picks in a repeat of the pattern to be woven. Bolts are passed through these holes, and upon the bolts the tappet plates, with similar holes, are placed. The level of the plates ranges but slightly above that which keeps the treadle bowl at rest; but within the plates are slots for receiving the ends of

those parts of the tappets which are to act as sinkers on the treadles. Say that we have eight heald shafts and eight picks upon each. No. 1 heald shaft is to be lifted at picks 2, 3, and 5; then into the slots of 2, 3, and 5 the sinker plates are inserted, while all the others are left bare. Heald shaft 4, on the contrary, is to be depressed at picks 2, 3, 5, then sinkers are to be put upon all the other slots, viz. 1, 4, 6, 7, 8, and so on. With such a base the tappets can be arranged in any order required by the pattern. The treadles are placed beneath the loom, the bowls in touch with the tappet plates. The reversing

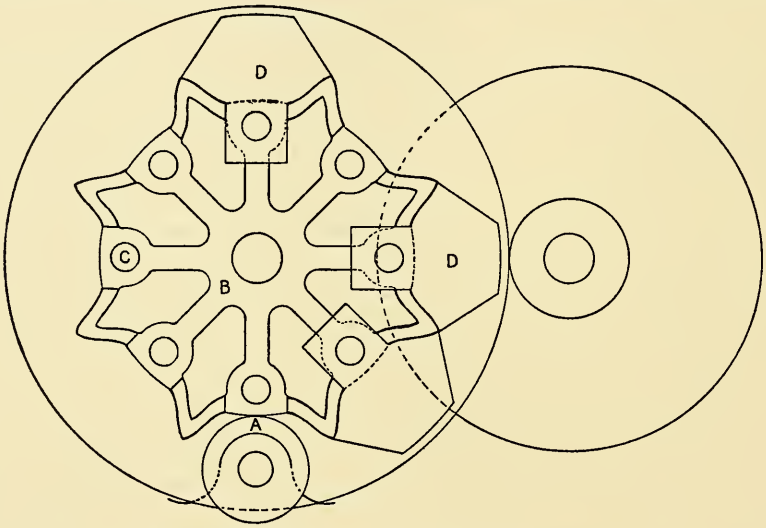


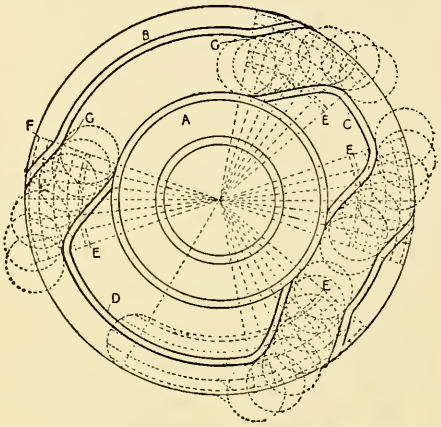
Fig. 268.—Jamieson's Negative Tappet
A, Bowl of treadle. B, Spur wheel. C, Bolt holes. D, Sinker plates.

motion is generally accomplished by means of simple springs placed above the heald shafts, though any other of the over motions may be employed. It is found that the bolts upon this form of tappet are apt to work loose, but a careful worker can obtain good results with it.

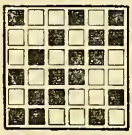
Various other negative tappet mechanisms are employed in factories both in this country and abroad; but the Jamieson tappet illustrates sufficiently the principles of the class, which is, after all, not very important.

The Woodcroft Tappet.—Positive tappets, though primarily nothing more than cams with an outer flange, began a new range of development which has practically issued in the form of heald-shaft appliances we have mentioned. In the main the drawing plan of a positive tappet does not differ greatly from that of the negative designed for

the same pattern. Half-circles the diameter of the treadle bowl are sufficient for the outline of the negative tappet, but for the plan of the positive tappet the full circle of the treadle bowl is required. The line of the outer flange is drawn upon tangents from those circles; but from such a plan only an abstract and ideal tappet could be formed. An allowance of about $\frac{1}{8}$ in. is made in practice between the flanges, to give free play to the treadle bowls. A glance at the plan of a positive tappet shows that the treadle bowl is in the grip of the plate continuously; it either depresses or lifts the treadle all the round (fig. 269). Thus, from an intermittent motor the tappet has become a constant mechanical force. Very probably the original inventors of the positive tappet had no other object than to get rid of the necessity for supplementary reversing motions; but the idea came, with consequences of a far-reaching nature.



Picks in 1 rev.



Pattern

Fig. 269.—Draft for Six-pick Positive Tappet

A, Tappet ring. B, Outer flange. C, Short-lift end of tappet. D, Long-lift end of tappet. E, E, E, Segments of inner circle. F, Segment of outer circle. G, G, Segments of middle circle, showing also points of intersection.

One of the first lessons derived from the positive tappet was that the whole tappet needed not to be an eccentric, and that therefore any form of flange which would impart the up-and-down motions to the heald shafts at the proper intervals would serve. Having the treadle bowl in possession all the round, the tappet must impart to it a form of motion for every pick, no matter what the motion might be. The depresser and lifter sections of the tappet were seen thus to be simply the reverse of each other. Acting upon this idea, Bennet Woodcroft in 1838 brought out a patent positive tappet, consisting of sections, one section to every pick in the round. Advancing a step further, he discovered that one set of plates could be made to serve for a pattern containing a large number of picks and any smaller number of picks which was an aliquot part of the greater number. Say that the maximum number of picks for which the whole plate has been cast is 24, then we may obtain upon it 12, 8, 6, 4, 3, or 2 picks. In order to

make this quite clear, let us take a simple instance of a single plate (fig. 270).

The number of picks which this plate is capable of giving to the round is eight. To every pick a section of the plate is made; there may be four depressers and four lifters, or three of one and five of the other. We may have a stock of both capable of making fifty such plates. The size of the sections is conditioned by the number of picks contained in the round of a given size of tappet. For the sake of convenience we premise that the outside flanges are depressers and the inside flanges lifters; but, as we shall show hereafter, the functions may be reversed. Counting from right to left, section 1 is a depresser, 2 a lifter, 3 a depresser, 4 and 5 lifters, 6 and 7 depressers, and 8 a lifter. All the sections are precisely the same size and all for the same length of pick and dwell, each fitting into each, and forming a complete circle. Upon sections 2, 4, 5, and 8 there is a flanged arc half the depth of the treadle bowl from the edge of the outer end; towards the inner and narrower end there is a small bar, and on the centre of the section, almost on the inner edge, another and smaller flange or bar. Upon sections 1, 3, 6, and 7 a flanged arc curves in from the outer edge, each exactly the converse of the arcs of the other sections. Farther in are small flanges useful either as grading terminals to the depresser flanges or as carriers of the bowls on to the inner ring of the whole plate. Next below are small flange bars similar to those on the depresser sections. Through the centre of each section a bolt hole is pierced. As they stand, the sections have no unity; they lie together in close enough order, but would hardly work in that condition. To give them unity and form a complete tappet plate, we have a centre ring, flanged on the outer edge, and pierced with bolt holes, which fits into the bars we have noted on all the sections. When this ring has been fitted in, the plate is complete.

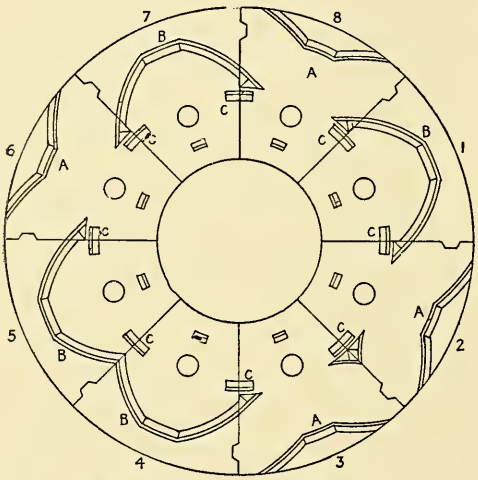


Fig. 270.—Woodcroft's Positive Tappet

A, A, A, A, Depressing flanges. B, B, B, B, Lifting flanges. C, C, C, C, C, C, C, C, Segments of tappet ring. 1, 2, 3, 4, 5, 6, 7, 8, Tappet plates.

The eight sections of the other seven plates are assembled in the same fashion, each in its proper place for the pattern. Now they are ready to be fixed on the tappet wheel. Pierced with bolt holes, the tappet wheel is furnished with long bolts and nuts for holding all the plates in unity. Section after section, plate after plate, the whole tappet is built up and ringed on the bolts, then firmly screwed down.

Application of the Woodcroft Tappet. — Few tappets are so generally useful as the Woodcroft. It is employed by weavers of heavy fabrics in cotton, wool, and linen, for carpets, and many other textures. The adaptability of the appliance is extreme, being capable not only of almost endless change in the plates, but also of sitting in any position on the loom. To illustrate this, let us take an example as basis.

Taking the eight-shaft tappet already noted, and following its lines, we place it to the right-hand side of the loom, with the treadles under the level of the tappet centre. Each outer flange acts as a depresser and each inner arc is a lifter. The treadles are fulcrumed out beyond the tappet wheel, and upon them are anti-friction rollers, or bowls, which are in position to be acted upon by the tappets. From the end of the treadle, straps and cords pass to the jack levers hanging at right angles to the treadles, the ulterior ends of the jacks being connected to the heald shafts by similar cords and straps. Commencing with section 1, which is a depresser, treadle 1 is brought down, causing heald shaft 1 to rise, through the medium of the jack. Section 2 is a lifter, and it elevates the treadle, causing the heald shaft to sink. Right round, at every pick, the sections cause either a rise or a fall of the heald shafts; and every separate plate operates in precisely the same fashion upon its attached heald shaft.

Reverse the position of the treadles and fix them above the tappet centre (fig. 271). The tappets placed in the same order will act in precisely the opposite way. The outer flange of the tappet is now on the higher level in relation to the treadle bowl, and causes it to rise, while the other section or inner flange causes it to sink down.

By a simple manipulation we can change the tappet from the right to the left side of the loom; or we can change the direction of the revolution in relation to the crank shaft, and adjust the tappets to that condition. Scarcely a conceivable difficulty in loom structure can occur for which the Woodcroft tappet cannot be adapted.

It must be admitted, however, that the tappet does not suit well

light and tender warps. A certain degree of vibration results from the large number of sections of which the whole tappet is composed. Moreover, to hold the treadle bowls in continuous contact with the tappets, a considerable degree of strain is put upon the warp, unless the whole mechanism has been perfectly adjusted. For strong fabrics this is no drawback. The full capacity of the Woodcroft tappet is about thirty-two picks, though fifty have been operated.

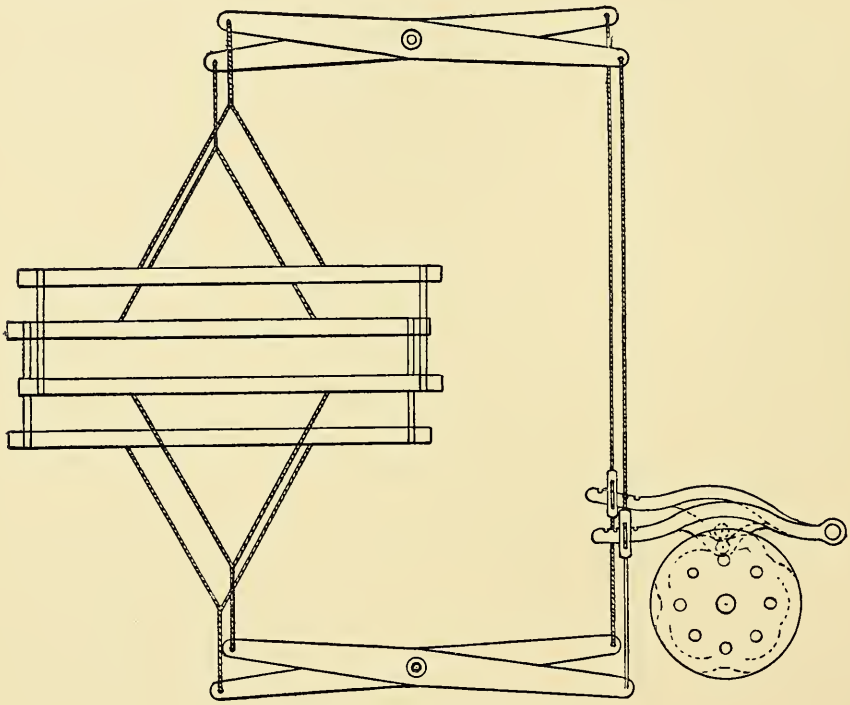


Fig. 271.—Action of Woodcroft's Tappet

Chain Tappets. — From the positive tappet to the heald-shaft mechanisms, which have little of the tappet form about them, was but a step. Shortly after the appearance of Woodcroft's tappet, George Clarke brought out a rotating chain tappet, combining in a tentative, experimental way the common form of tappet with the chain. He patented it in 1840. Small notice was taken of the innovation for a time. About nineteen years later John Knowles took out a patent for an improved tappet, approximating to the oscillating form. After that William and Thomas Nuttall, Messrs. Grubb & Hall, and several others brought out patents on the same principle, securely establishing the chain tappet among shedding appliances.

The details in which the various chain tappets differ from each other are of small consequence. The leading idea is that a tappet should be composed of as many chains as there are healds on the loom, the links on the chains being equal to the number of picks in the pattern, or, in other words, the round of the tappet. In general structure the chains closely resemble the driving chain of a common bicycle. The links are connected with each other and the rest of the chains by spindles from the tappet blocks, to which they are all secured. Links are of two kinds, the one a roller for lifting and the other a collar for depressing the heald shaft. We now see the flanges and the plates separate, the flanges becoming a chain and the plates the star wheel carrying the chain round. To carry the analogy further, we might say that the bolts of the sectioned tappets had been made into spindles, upon which the links freely work.

Chain Tappet Structure.—As in all tappet appliances, one part or section is assigned to each pick of the loom. Each link on every chain represents a pick, or a movement of its heald shaft. The chains may therefore be of any length, and the rollers and collars linked together in any order desired by the designer. Let us suppose we collect together the links for a sixteen-pick pattern, with sixteen heald shafts. Of course, we could work such a pattern, at any rate a pattern of as many picks, with far fewer shafts, but we adopt the supposition hypothetically only. Shaft No. 1 lifts at pick 1, sinks at pick 2; lifts at picks 3 and 4, sinks at picks 5 and 6; lifts at picks 7, 8, 9, sinks at picks 10, 11, 12; lifts at picks 13, 14, and sinks at picks 15, 16, in order. We need not detail the movements of other heald shafts at present; one chain has been obtained, and we know the order in which the links have to be set. No. 1 is a roller link, 2 is a collar, 3 and 4 are rollers, 5 and 6 are collars, and so on. After all the links have been gathered, it is not permissible to string them all in one. The links are divided into two sections, one consisting of the links for odd picks and the other of the even picks.

The Oscillating Chain Tappet Mechanism.—Understanding of the reasons for division of the tappet chain is impossible without some knowledge of the mechanism upon which it operates (fig. 272). The treadle sits above the tappet mechanism, its bowl, when in equilibrium, resting above the centre of the latter. On each side are the tappet plates, formed to impart an easy and smooth motion to the treadle bowls when in contact. Slotted into the plates are levers, turned at angles toward each other, upon the ends of which weighted levers are

attached. The two pairs of levers form an elbow, the lower arms of which are the weighted levers. Beneath the latter revolve two star wheels, or barrels, geared in bearings on the tappet, and allowed to run freely. Upon the star wheels the chains of the tappets are placed. A mechanism rather complex causes the tappet to oscillate; but it may be left out of account at the moment, the present object being to view the chain tappets simply. Resting upon the chains, the weighted levers are subject to the action of roller or collar as either comes uppermost on the star wheel. When a roller comes round, the lever is lifted, causing the connected lever having fulcrum in common with it to lift the tappet. Actuated by a stud on a pin wheel in the middle space between them, the star wheels move round and bring up another link, this time, say, a collar, and the lever, held down by its weight, keeps the tappet plate on the lower level, making the treadle bowl sink.

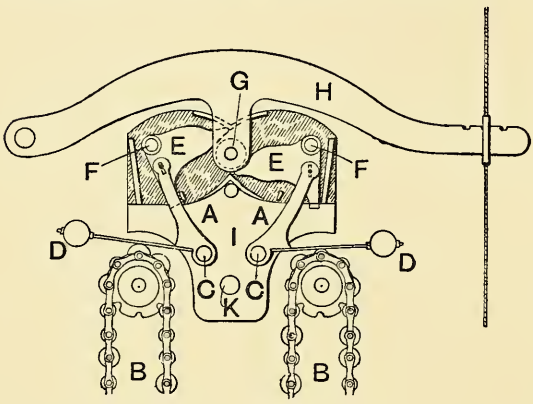


Fig. 272.—Oscillating Tappet

In this tappet the levers A A are actuated by the rollers and collars of the chains B B. The levers are pivoted at C C and weighted at D D. By means of pins working in slots they move the tappet plates E E, which are centred at F F. When one of these is depressed the bowl G of the treadle H will follow the upper surface of E as the tappet I (driven by mechanism not shown) oscillates on the stud K. But when E is lifted by a roller of the chain, the bowl passes beneath it and depresses the treadle.

While the chains are turning round, the tappet itself is rocked to and fro, causing the treadle bowl to touch on the chain at one side and then the other. The main object of the oscillating motion is to bring the tappet into contact with the chains alternately. The lift or sinking of the treadle bowls is the work of the chains and levers. With this tappet patterns of from 80 to 100 picks can be woven, the chain being in two parts.

With the object of simplifying the mechanism, the Nuttalls devised what is called "Nuttalls' Chain", largely employed in carpet manufacture and heavy woollens (fig. 273). Composed of chains similar to those on the oscillating tappet, this contrivance acts directly on the heald-shaft treadles. The chain barrels, mounted in suitable bearings, and parallel with each other, carry the chains round at the speed required by means of spur wheels connected by a small wheel in the centre which gives them a rotation in the same direction. Some

important differences between this tappet and the others noted must be observed. The fulcrum of the treadle is fixed exactly in the centre of the two chain barrels. Consequently it is impossible for a roller to be uppermost on both barrels at once, because the one would negate the other. The chains must be arranged, therefore, so that a collar on the one comes opposite a roller on the other. A link in both chains is thus required for a single pick. Say that the right-hand chain is to lift and the left-hand chain to depress a heald shaft. A roller on the former comes round and lifts the treadle at the outer end, bringing down the inner end of the treadle and elevating the shaft through the agency of the cords. Next, a barrel on the left-hand chain is brought into play; it lifts the inner end of the treadle and depresses the shaft. The one chain is thus seen to be practically inactive while the other is making a change in the motion of the heald shaft. The device has the advantage of simplicity, but it does not suit weaves in which a large number of picks are required to form a pattern.

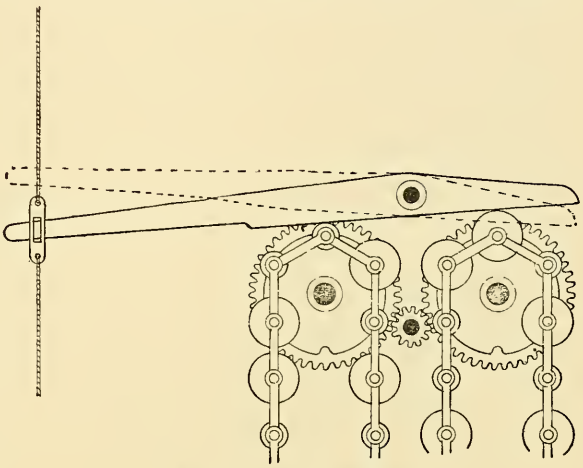


Fig. 273.—Nuttall's Chain Tappet

Scroll tappets and various chain tappets of special design are being constantly devised and improved; but we have already exceeded the limits of that proportion of space which the importance of the tappet demands.

Tappet Problems.—All forms of tappet shed the warp, but some tappets may make a wider shed than others, and other warps may need less of a lift than some. The tappet-shaft speed has also to be ascertained. When a tappet can put in forty picks in one revolution, its speed must be very much slower than a tappet which only puts in two picks, unless the latter is to be driven very slowly indeed. A loom which could put in forty picks while another was only putting in two would be a marvel in weaving; alternatively the two-pick loom would be absurdly useless. This is one of the points at which the essential unity of the loom appears. The tappet shaft is related to the

main crank shaft which drives the batten and slay; the size of the shuttle determines largely the depth of shed required; the speed of the whole loom fixes the rate of the tappet-shaft speed; the fittings of the treadles and tappets have a say in the lift of the tappet; the distance between the cloth, or fell, and the point where the shuttle enters the warp affects the adjustment of the tappet mechanism. Involved as the subject seems to be, clear solutions can be arrived at by taking each main problem singly, and using the results so obtained for solving the others.

To Find the Size of Tappet Required to Produce a Lift of 4 in.—Before entering into the subject, it is well to define terms. By size of tappet we do not mean the whole diameter, but the difference in the distance from the centre to the smallest and to the largest circumferences of the tappet. The factors in this problem are: 1, the length of the treadle; 2, the distance of the treadle bowl from the fulcrum or treadle pin; 3, the length and relations of the levers controlling the healds. For example, with the mountings of jacks and half-moon levers employed on many tappet looms, we find all the factors at work. In this case the jacks and half-moon levers, by the difference of their lengths, correct the power of the other factors to increase the lifting of the tappet above its size, and simplify the problem by making a 4-in. tappet perform a 4-in. lift. Suppose we had only the length of the treadle, the distance from the treadle bowl to the fulcrum, and the depth of shed to consider. Then as the length of the treadle is to the distance of the treadle bowl from the fulcrum, so is the latter to the depth of shed. Let the treadle be 30 in., the distance from fulcrum to bowl 20 in., and the shed 4 in., then: $30 : 20 :: 4 = 2\frac{2}{3}$ in. Now, if the half-moon levers and the jacks were of equal length, this would give the size of tappet required; but in actual fact the half-moon levers are much shorter than the jacks. Say that the jacks are 9 in. and the half-moon levers 6 in. long, then: $6 : 9 :: 2\frac{2}{3} : 4$. The jack alone would multiply the stroke of the tappet by its own length, viz. 9 in.: but the half-moon levers would reduce it by their length, 6 in.; multiplying the size of the tappet required under the supposed conditions by 9 and dividing by 6, we obtain the actual size of tappet needed, viz. 4 in.

Conditions in which the Tappet is smaller than the Depth of Shed Required.—On many tappet mountings the action of the tappet on the heald shafts is direct. The worker has therefore to consider only the length of treadle, the distance between treadle bowl and

fulcrum, and the depth of shed required. Suppose, then, we have a length of treadle, 19¼ in., a distance from treadle bowl to fulcrum of 11¼ in., and a depth of shed required, 3.33 in. Then 19.25 : 11.25 : : 3.33 : 1.94, which is the size of tappet required.

Further example is hardly necessary. From those given it is easy to see that the longer the relative distance between the treadle bowl and the fulcrum, as compared with the whole length of the treadle, the less the lifting power of the tappet. And also, that intermediaries counteract each other to the degree in which they are unequal.

Large and Small Tappets.—Sizes of tappets vary. To put twenty-four picks on to the round of a tappet 5 in. in diameter is a practical impossibility. Plain tappets used on cotton looms are generally about 5 in. in diameter; but some tappets are over 17 in. in diameter. Hence some confusion arises in the minds of those who are not acquainted with the practical facts, or young students who are trying to acquire knowledge of the trade. The lift of the tappet, technically named the *size*, is the difference between the radius of the large and small sides of the tappet, or the depressing and lifting parts of the machine. By a combination of levers it is possible to obtain a lift of 4 in. from a tappet mechanism which lifts not more than an inch at the tappet wheel. As we have indicated, it is often necessary to employ levers which reduce as well as levers which heighten the effect of the tappets. Every problem, however, can be resolved into a calculation in simple proportion.

Relation of Tappet to Size of Shuttle.—All over the whole weaving industry shuttles range in depth from about ½ in. to 2 in. When the shuttles are very large, as in the weaving of jutes and carpets, the whole looms are in proportion. At first sight it seems, therefore, an unnecessary trouble to calculate the size relations of tappets to shuttles. Few tappets give less than 2 in. in depth of shed. Where, then, lies the problem? The whole loom, it is to be borne in mind, is constantly in motion. If a certain pause is obtained on the heald shafts for the pick, the batten is always going. Moreover, we can only allow a given space between the shuttle and the last pick inserted, technically named the *cloth fell*. The depth of the whole lift may be ample, and yet the shuttle fail to pass through. For simplicity of illustration, let us suppose the shuttle is 1 in. deep: what depth of shed is required to allow that shuttle free passage? To ascertain that, we must know what is the traverse of the batten, the distance between the cloth fell and the front heald shaft, and the

position of the batten at the time of the pick. Assuming that the commencement of the pick is timed for the moment when the batten is in the balance, or when the crank is in the bottom position, we assemble the factors. The front heald shaft is 8 in. from the cloth fell, the traverse of the batten is 6 in., and the depth of the shed at its highest, 3 in. When the batten is 3 in. from the cloth fell, therefore, the size of the shed is reduced to 1½ in., which gives ample room for the shuttle to pass through.

Speed of Tappets.—The batten of the loom, carrying the reed, shuttle, and shuttle boxes, and otherwise known as the going part, is driven directly by the main crank shaft. It is necessary, therefore, that the crank shaft should revolve once for every pick of the loom. From it the whole of the other parts of the loom take their timing. The tappet shaft is driven directly or indirectly from the crank shaft. For this purpose a pinion wheel is fixed on the end of the crank shaft, which works into the wheel on the end of the tappet shaft, or intermediate wheels working into the latter. If, as we have said, the crank shaft revolves once for every pick, and the tappet shaft revolves once to every repeat of a pattern of any given number of picks, the relative speeds of the two shafts must vary according to the number of picks contained in one repeat of a pattern. In small patterns the wheel on the end of the crank shaft is a change wheel, the number of teeth on the set of wheels usually employed ranging from twenty to sixty. The corresponding wheel on the tappet shaft is fairly large, containing 120 teeth. Obviously the change driving wheel of 60 teeth just suits the plain tappet, with 2 picks to the round, and a wheel with 20 teeth will admit of 6 picks to the round. But we have mentioned 16, 24, 32, and even more picks as being in a single pattern, and therefore in a single round of the tappet. Two practical difficulties meet the weaver or loom builder here. On the one hand, a pinion wheel with fewer than 20 cogs, or teeth could not be put on the loom crank shaft with safety, because the metal left after boring would be too thin; on the other hand, even a wheel of 20 cogs is so small as to render the maintenance of contact with the tappet wheel a matter of some difficulty. If the direction of the revolution of the tappet wheel were a matter of indifference, we could solve the whole problem by putting on a small pinion with as few cogs as might seem needful for an intermediate; but the tappet shaft and the crank shaft would then revolve in the same direction, which is not usual. A better method is to put on

a train of wheels. In some cases five wheels are employed; but the method which meets all the needs of the case is to compound the wheel driven by the crank shaft with a smaller one driving the tappet shaft. In the whole problem there are five factors: the crank-shaft change wheel, the compound large wheel, the compounded small wheel, the tappet wheel, and the number of picks on the tappet. Each one of these factors may be an unknown quantity, with the exception of the tappet wheel, which almost uniformly has 120 teeth. We have therefore in four instances to proceed from known to unknown quantities. The rules are:—

1. **To Find the Number of Teeth Required in the Compound Large Wheel.**—Multiply the number of teeth in the driving wheels by the number of picks to the round, and divide by the number of teeth in the tappet wheel.

Example: Given 30 teeth in the crank-shaft wheel, 15 teeth on the small compound wheel, and 12 picks to the round, with 120 teeth on the tappet wheel, then: $30 \times 15 \times 12 \div 120 = 45$, which is the number of teeth in the large compound wheel.

2. **To Find the Number of Teeth Required in a Change Wheel.**—If we multiply the large compound and the tappet wheel — the two driven wheels—and divide by the number of teeth in the small compound wheel multiplied by the picks to the round, the result will appear.

Example: Suppose the number of picks to be 12 and the teeth on the small compound wheel 15, the large compound to have 45 teeth and the tappet wheel 120, then: $120 \times 45 \div (12 \times 15) = 30$, the number of teeth in the change wheel required.

3. **To Find the Number of Teeth Required in the Small Compound Wheel.**—Multiply the driven wheels together, and divide by the change wheel multiplied by the number of picks.

Example: The large compound wheel has 45 and the tappet wheel 120 teeth; the change wheel has 30 teeth, and number of picks is 12. Then $120 \times 45 \div (30 \times 12) = 15$, the number of teeth required on the small driver.

4. **To Find the Number of Picks on the Round a Given Set of Wheels will Give.**—Multiply the driven wheels and divide by the drivers.

Example: The driven wheels are the intermediate and tappet wheels containing 45 and 120 teeth respectively; the drivers are the change wheel, with 30, and the small compound wheel, with 15,

teeth. Then $45 \times 120 \div (30 \times 15) = 12$, the number of picks on the round.

When, as may happen for various reasons, a fifth wheel is brought in between the small compound driver and the driven tappet wheel, it acts as a carrier, and does not affect the relations of the wheels to each other, though the direction of rotation is necessarily changed.

CHAPTER V

The Dobby

Dobby, Witch, or Wizard.—In its highest forms the machine which has been variously named dobby, witch, and wizard closely approaches the Jacquard. It is not to be inferred, however, from the mere accident of resemblance that the former is anything like an adaptation of the latter. The dobby was being evolved upon its own lines long before the Jacquard became generally known to the weavers of this country. It was, in fact, originally an appliance of the hand loom, though now recognized as one of the most serviceable of shedding appliances for the power loom. The dobby is a growth of the trade; no single individual can claim to have invented it. Few appliances are employed in so great a variety of forms. We find it on fast looms and slow looms, on light looms and heavy, on hand and power looms, making centre sheds, open, closed, semi-open, and as positive, negative, or other motions. Undoubtedly, the tappets, the Jacquard, and the figuring harness have all helped to modify and improve the dobby, hints from the one and the other being embodied in it from time to time.

Dobby on the Hand Loom.—Perhaps the full value of the dobby is best exhibited on the hand loom; it stands there, at least, free from all additions, and can be understood more easily in that form than when surrounded by the complex appliances of the power loom.

A stout frame placed in the middle of the hand loom above the heald shafts holds the dobby mechanism (fig. 274). Within the upright spars of the frame what is called the *block* is fixed to slide in grooves, the block containing a pair of horizontal iron bars, or knives. A treadle under the loom operates the block and bars by means of a lever; when the treadle is depressed, the lever lifts the knives. Two

rows of hooks stand vertically adjacent to the two bars, which we may name, for convenience, the front and back rows respectively. When the whole machine is at rest, the back row of hooks rest upon the

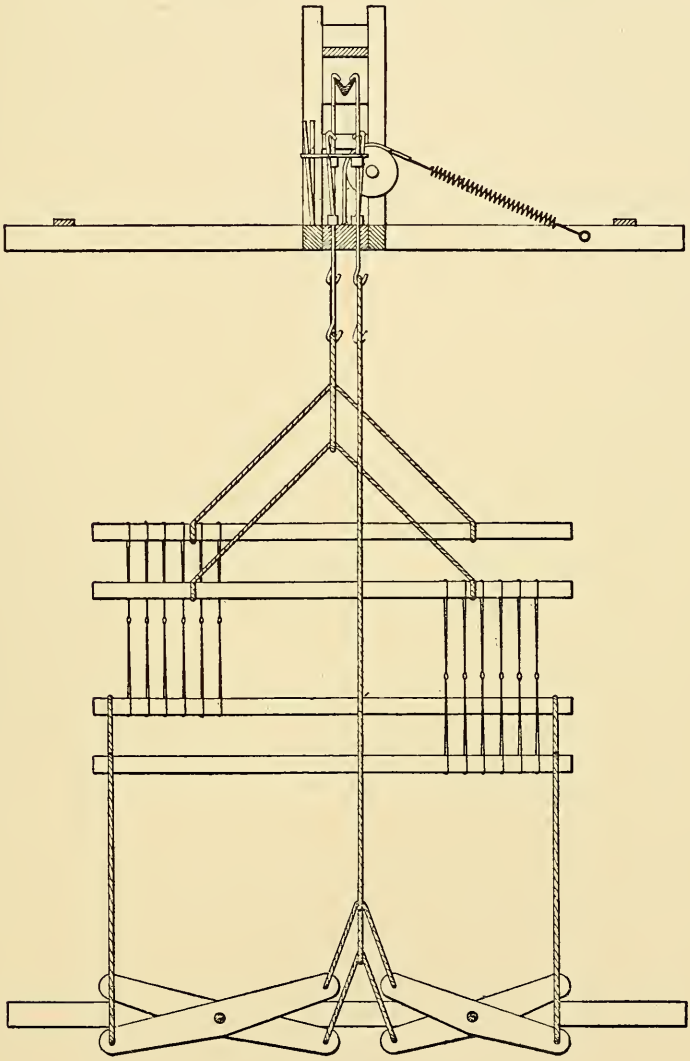


Fig. 274.—Witch or Dobby Shedding Arrangement for Hand Loom

back knife, the front row inclining away from the front knife. Straps depend from the front row of hooks, and cords from the top shaft of the heddles are attached to them. The straps on the second row of hooks are fastened to cords or wires, which are linked into the interior ends of small jack levers, of which there are two pairs,

fulcrumed on the framing in the base of the loom. The exterior ends of the jacks are attached to the bottom shafts of the heddles. The back row of hooks, therefore, when drawn up by the knife or bar, must act as sinkers of the heald shafts to which they are attached. In the same way, the front hooks act as lifters. We have not yet got a full view of this part of the mechanism, however; there is another and very important piece to be noted. Round each pair of front and back hooks a horizontal wire is looped, one end of which is riveted to an upright flattened spring wire, so that the pull of the latter will drag the two hooks forward, taking the front hooks off the front knife, and bringing the back hooks on to the back knife.

These are the main features of the internal mechanism of the dobby, but there is another very important factor. At the side, and touching the surface of the spring wires, is a cylinder, carrying upon it a chain of flat wooden bars, named *lags*. These bars are perforated in such a way that each hole comes opposite a spring wire. When in working order, the lags are equipped with pegs which fill up certain holes, and pressed against the spring wires, pushing the front hooks over the front knife and the back hooks off the back knife. The exact order in which the lags are pegged does not matter meanwhile; it is enough to say that they are filled up in that manner.

A dobby can be employed in working forty-eight heald shafts, but we shall confine observation to a single pair to save trouble and complexity. Each heald shaft has its own pair of hooks, the front one to lift and the back one to depress. Suppose, then, the lag opposed to spring wire 1, controlling heald shaft 1, is pegged, and that the lag hole of heald shaft No. 2 is open. The treadle is pressed down, with the lag close up to the spring wires, sending No. 1 forward and letting No. 2 through. At that moment the knife block lifts. The hook of heald shaft 1 has engaged the front knife, and the back hook of that pair is sent away out of the path of the back knife; heald shaft 1 is lifted, while the back hook, which otherwise would act as a sinker, is thrown out, letting the jack levers below free to yield to the pull of the lifting knife. On the other hand, the front hook attached to heald shaft 2 has been allowed to remain out of the path of the front knife; but the back hook has held on to the back knife; when the block lifts, therefore, the back hook draws at the interior ends of the jacks on the bottom shaft of heddle 2, and drags it down. At the next turn of the cylinder a lag is brought round pegged in hole No. 2 and

open to the end of the spring wire of heald shaft No. 1. Heald shaft 2 is drawn up and heald shaft 1 depressed.

Lags and Pegs.—For the sake of illustration we have viewed only two heald shafts and two lags; but in practice we have to work any number of shafts ranging from six to forty-eight. There are many forms of lag, and different methods of operating them; in some power-loom dobbies, as we shall see, the lags are displaced by cards. Being chains, lags may be made any length, containing one, two, three, or as many repeats of a pattern as may appear advisable. Dobbies may be right-handed or left-handed, according to the position

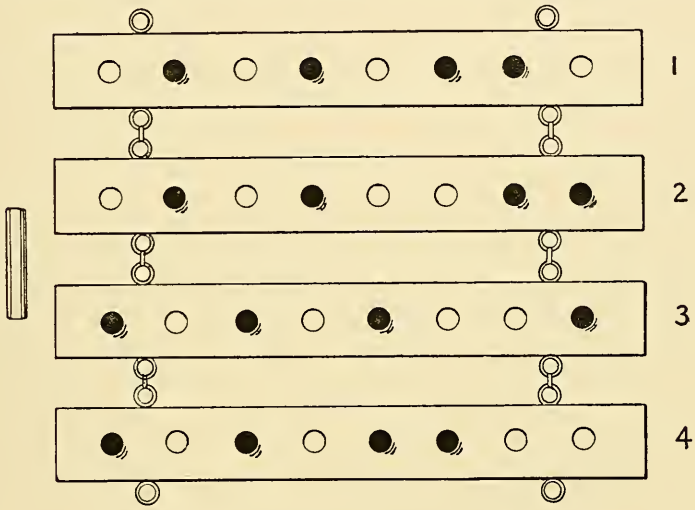


Fig. 275.—Lags and Pegs (a peg is shown separately on the left)

of the treadle on the hand loom or the driving rod on the power loom. When the motor is on the left side of the weaver, as he faces the loom, the dobby is right-handed; when the opposite is the case, the dobby is left-handed. In pegging, it is necessary to consider which hand the dobby belongs to, the rule being that the first lag which turns in towards the dobby mechanism is the first to be pegged.

Suppose we elect to weave a pattern containing four picks and eight threads or ends (fig. 275). For this pattern we require only four heald shafts, because each shaft carries two threads; but the shafts are not the factors in the lagging; it is the threads operated. Therefore, each lag must contain as many holes as there are threads—in this case eight. Reading from right to left, say, we peg lag 1, thus: Hole 1 open, hole 2 pegged, hole 3 pegged, hole 4 open, hole 5 pegged,

hole 6 open, hole 7 pegged, hole 8 open. Lag 2: hole 1 pegged, hole 2 pegged, hole 3 open, hole 4 open, hole 5 pegged, hole 6 open, hole 7 pegged, hole 8 open. Lag 3: hole 1 pegged, hole 2 open, hole 3 open, hole 4 pegged, hole 5 open, hole 6 pegged, hole 7 open, hole 8 pegged. Lag 4: hole 1 open, hole 2 open, hole 3 pegged, hole 4 pegged, hole 5 open, hole 6 pegged, hole 7 open, hole 8 pegged. With this chain of lags we produce a fine pattern.

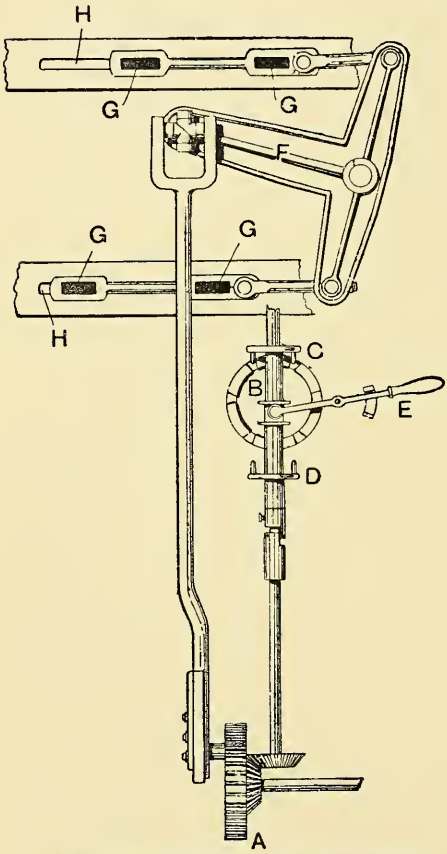


Fig. 276.—Keighley Dobby: Driving Mechanism

A, Compound pinion on crank shaft. B, Wheel on end of lag cylinder. C, D, Pin-wheels actuating B in opposite directions. E, Reversing lever. F, Elbow-lever driving the lifting bars or knives shown in section at G, G. H, H, The grooves in which the knives slide.

Upon the hand loom, the cylinder is usually an octagonal barrel, which is given one-eighth of a revolution every time the treadle works, bringing round a fresh lag every time. The cylinders of power looms are not so simple either in structure or in movement, and they therefore require to be noted in more detail.

The Keighley Dobby. — One of the most useful of the dobbies operated on the power loom is that known as the Keighley dobby, patented by Messrs. Hattersley & Smith in 1867, and since improved by many other inventors, as well as by Messrs. Hattersley themselves. Though recognized as belonging to one type, the different makes of Keighley dobby differ so much in shape and important details that it is rather difficult to make one stand for the class without omitting essential features. Probably the best plan is to take the very simplest form first, and then go on to study the particulars of one among the newest and best, without, however, specifying names.

A Simple Double-lift, Open-shed Keighley Dobby.—In every dobby there are what we might call the actuating parts and the driven parts, easily separable from each other, in the abstract at least. The

actuating parts are the lifting bars and the lag cylinder and pegged lags. In this particular machine we find them closely associated (fig. 276). Fixed to the loom crank shaft, a compound pinion wheel carries on its external side a pin upon which the shaft of an elbow lever is screwed. In the middle of the transverse arms a fulcrum pin holds the elbow lever on the loom. As the crank wheel turns round, therefore, it carries the shaft of the elbow lever with it, and imparts

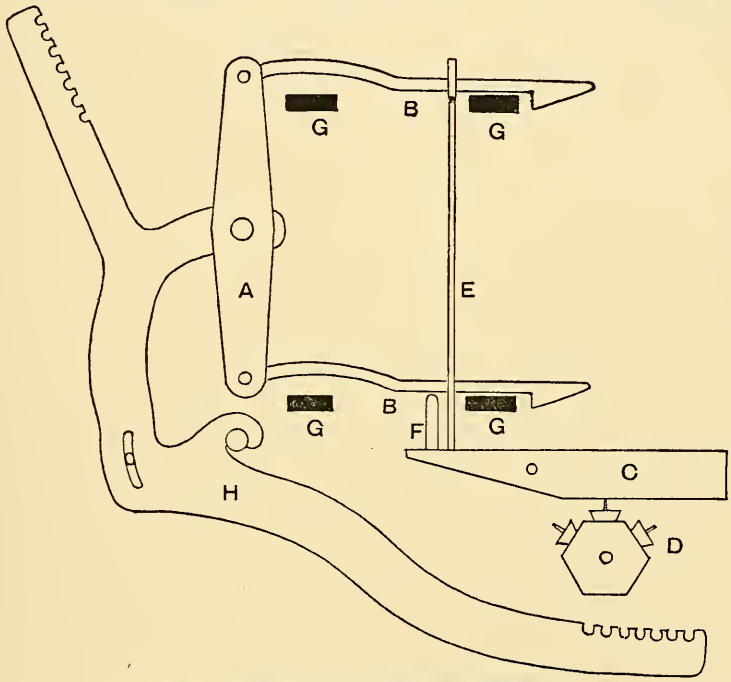


Fig. 277.—Keighley Dobby: Lifting and Sinking Motion

A, Rocking lever. B, B, Hooks. C, Lag lever. D, Lag cylinder. E, Needle lifting the upper hook. F, Finger lifting the sinking hook. G, Lifting bars or knives. H, Heald shaft lever.

to the arms of the latter a to-and-fro motion. On the ends of the arms the lifting bars or knives of the dobby are placed.

A pinion on the inner side of the compound wheel turns a bevel wheel on the base of a shaft rising up to the end of the lag cylinder. Upon the shaft a pair of movable little wheels sit at right angles with the end of the cylinder, both having pins which can give the cylinder a turn. When the upper of the small wheels is geared in the cylinder, the pins turn it in one direction; by moving a lever the upper wheel is put out of gear and the lower one brought into play, turning the cylinder in the opposite direction. Being driven by the same shaft, the lifting bars and the lag cylinder can be timed exactly to each other.

Now let us look at the driven parts, consisting of the hooks, or jack levers, the connecting wire, the lifting lever, the lever on the ends of the hooks, and the heald shaft lever, connected at both ends with the heald shafts by straps and cords (fig. 277). The heald shaft lever and the hooks lever are based on a common fulcrum, the former holding the latter firmly. Extending at right angles from the lever, the jack levers or hooks are held over the lifting bars, the one to lift and the other to sink the shaft to which its lever is attached. From a small lever below comes up a needle, or wire, the end of which is a slot holding the jack within it; beside the wire, on the same lever, is a small finger designed to act on the sinking hook or jack. Under the small lever is the lag cylinder. Each heald shaft has its full complement of driven parts—hooks, jack lever, heald-shaft lever, needle, and lag lever.

Having seen all the parts of the dobby, we can easily follow its motions. The crank shaft drives round the wheel carrying the pin of the elbow lever holding the lifting bars. From the pinion on the inner side of the wheel on the crank shaft, motion is imparted to the vertical shaft driving the cylinder and lags. The pegs in the lags lift the lever which pulls down the lifting hook, causing it to engage with the bars. The action of the bars is to draw the hooks, pulling the lifter in one direction and the sinker in the other, the combined action lifting the heald shaft. At points in the lag where no pegs are, the lag lever, finding no support, sinks, bringing up the small finger, which pushes the hooks out of the path of the lifting bars, imparting a sinking motion to the attached heald shaft. When it is desired, the motion of the lag cylinder can be reversed by changing the pinned wheels on the upright shaft.

Improved Keighley Dobby.—It is possible to describe this dobby from the one already detailed by simply noting the improvements, for the main structures are practically identical. But clearness, which should always be the aim of mechanical description, will be more certainly attained by treating both independently.

The driving section of this dobby consists mainly of a three-armed lever, one arm extending horizontally, and the other two in a vertical position, all moving upon a fulcrum in the centre. To the end of the horizontal arm a vertical rod is attached, the rod being geared into the crank shaft at the bottom of the loom by means of crank pin or pinion. At each end of the vertical arm of the triple lever horizontal bars are fixed, these being variously named by the trade *knives*,

draw bars, *lifting bars*, or *levers*. When the horizontal arm is moved up and down by the motion of the crank, the vertical arms naturally move to and fro, withdrawing and thrusting in alternately the knives fixed on their ends. Instead of having an independent motion, the lag cylinder derives its rotation from the triple-armed lever. On the lower vertical arm a ratchet pawl is fixed which engages with the end of the cylinder barrel, which, being octagonal in form, lends itself to the purpose. At every oscillation of the vertical arm the ratchet pawl gives the cylinder barrel a thrust and sends it round one-eighth of its circumference.

Turning now to the driven section of the dobby, we find some

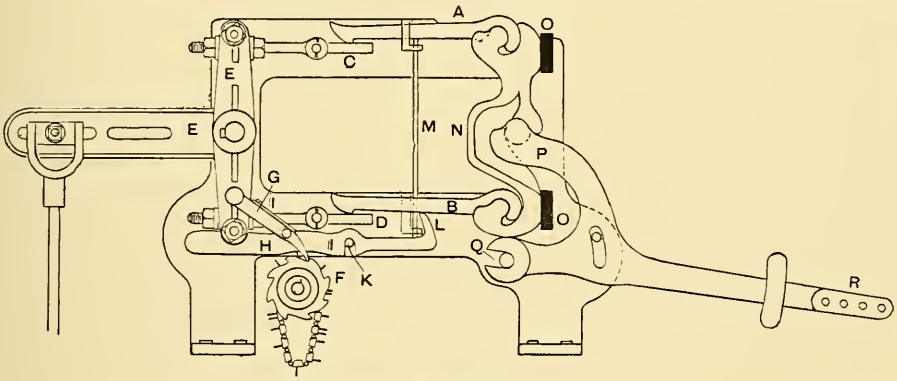


Fig. 278.—Improved Keighley Dobby (Ward Bros.)

A B are the hooks, and C D the draw knives, driven by the three-armed lever E. F, The lag barrel turned one notch at a time by the pawl G, which is jointed at H and held stiff by the spring I, which, however, gives in case of any obstruction. I is the lever on which the lags act. It is hinged at K, and turned up at L to act on the hook B. A similar needle behind it lifts the needle M, which in turn lifts the hook A. N is a rocking bar held against the stops O by the crank-lever P, which is pivoted at Q, and connected to the heald shaft lever at R.

new features. A rocking bar fulcrumed on the end of the heald-shaft lever holds a hook on each end at right angles. The upper hook, which we name the *lifter*, is upheld by a vertical needle, or wire, the lower end of which rests upon a lever set above the lag cylinder. The other hook is also connected with a lever in the same place, but this lever has a curve on the end of it so that it may act freely on the end of the hook. Fine grids are made to support the needles and the hooks, the former in a vertical and the latter in a horizontal position. Extending from the framing of the dobby, supported by a fulcrum pin, the heald-shaft lever hangs over the centre of the shafts, bearing straps and cords attached to the shaft. The levers working under the needle of the lifting hook and the sinking hook have their heavy ends over the lag cylinder. Both levers are

positive in action, and the lags are therefore pegged for both, instead of the absence of a peg being allowed to operate the sinking hook, as in some forms of dobby.

For each heald shaft we require a shaft lever, a rocking bar, a pair of levers acting on the lag cylinder, two hooks—one to sink and one to lift—and one needle for the lifting hook.

Driven by the crank shaft, the draw knife of the lifting hook comes forward, and a peg in the lag pulls the needle down, causing the hook to engage with the knife; at the next motion the draw knife is withdrawn, taking the hook with it, and lifting the heald shaft. At the same time the reverse action takes place on the sinking hook. When the lifting knife is at the outer end of its slot, and the lifting hook drawn forward, the sinking knife will be at the inner end of its slot, with the hook corresponding in a position for drawing. Since the inward movement of the one is equal to the outward movement of the other, it follows that the centre of the heald-shaft lever will remain stationary. This gives the open shed. The lags for this form of dobby are double-pegged, one line acting on the needle and the other on the plain lever. Therefore the lags remain stationary for two picks. Then the ratchet pawl, which is kept in position by a small spring, acts on the lag cylinder, giving one-eighth of a turn, and bringing round another lag.

Cards on the Keighley Dobby.—Ever since the Jacquard loom mountings were adopted, the cards device for imparting pattern to heald shafts has been progressively applied to all kinds of shedding mechanisms. As a substitute for lags, cards have the advantage of cheapness. They are not so hard on the machinery as pegs, but that advantage may be outweighed by the delicacy of the needles required for the cards.

Substitution of cards for lags on the cylinder involves more than at first sight appears; the structure of the dobby itself undergoes modification. The lag levers are displaced by rows of vertical needles in contact with the cylinder at one end and the hooks at the other. Needles for the lower range of hooks are short, commonly about 3 in.; but the needles acting on the higher range of hooks require to be of some length, say from 12 to 13 in., according to the height of the mechanism. Sets of plates support the needles, the upper ends of which are tipped with broad flat discs for bearing on the hooks.

The cards are perforated with holes according to pattern, and

hung in lattice form upon the cylinder. The latter is not fixed vertically as on the lag machine, but is lifted up and down by a pair of levers actuated by a cam from the crank shaft of the loom. Every pick of the loom brings the card up into contact with the needles. The rotation of the cylinder, however, may be worked by the ratchet pawl of the lag dobby.

A greater difference occurs in the relation of the knives to the hooks. On the lag dobby the normal position of the hooks is out of contact with the knives, and the function of the pegs is to bring them into contact, or so many of them as there are heald shafts to be lifted. On the card dobby the hooks normally rest on the knives, and the action of the cards is to lift those out of contact which are not to be brought into play. The actual effect, in all ways, is precisely the same; the piercing of the cards and the pegging of the lags is the same action, both being designed to produce heald-shaft motions.

Other Improvements.—This dobby has been a great favourite with weavers of all classes of fabrics, and after the patent expired it immediately became the object of attention from machinists. On some of these improved dobbies the levers are dispensed with in the lag mechanism, and the lags are set directly to act upon the hooks. In others, again, improvement has been concentrated upon the lag cylinder and the form of the pegs, the object being chiefly to reduce vibration and make the pegs last longer. The setting and shape of the heald-shaft levers have also come in for special attention. These modifications, however, belong rather to the machinists' catalogues than to a work of this kind.

A Dobby with Needles.—In some particulars the lag cylinder suffers in comparison with the card cylinder, and the pegs do not obtain the same degree of favour as the needles. Experienced weavers and manufacturers whose aim has been to produce quality in goods will tell us that, next to tappets, lag dobbies are the best shedding appliances, and that the latter will never be displaced by what they justly call spurious Jacquards. We have to take facts as we find them, however, and, explain it how we may, the Jacquard form is steadily displacing the lag dobby. The change observed upon the Keighley dobby has been more pronounced on others. In fact we have to consider a whole class which never was anything else but needle and card dobbies.

Dobby with Horizontal Needle.—The machine known as the *single-lift dobby* was among the first of this class, and, though defective in

some particulars, it still finds use (figs. 279 and 280). The frame is placed over the centre of the loom, the ends of the vertical hooks being above the middle of the shafts. The hooks are long wires curved at both ends, the lower end to hold the straps and cords or wires from the upper of the heald shafts, the upper end to catch into the *griffe*, as the lifting bar in this kind of machine is named. A metal rack hinders the hooks from falling down farther than the re-required level. Each hook passes through the eye of a horizontal needle; as this needle is the means of lifting the hook on or off the griffe, it and its connections are worthy of special observation.

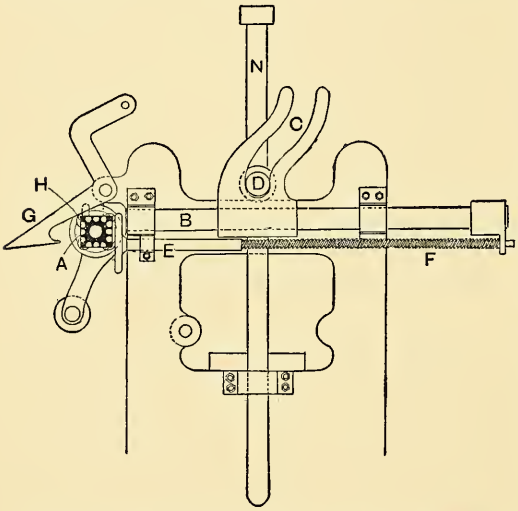


Fig. 279.—Jacquard Dobby: Mechanism actuating the Cylinder

A, Cylinder carried in open slots in bars B. C, Fork attached to B, and actuated by the bowl D working on a pin in the upright bar N. E, The hammer to steady the cylinder. F, Spiral spring. G, Hook to turn round the cylinder by holding one of the projections H on the "lantern" as the cylinder runs out.

All the needles are contained within the framing, perforated plates at front and back holding them in position while allowing them free motion to and fro. Each needle has two eyes, the one letting the hook through and the other taking in a spring wire fixed on the arm of a flat bar above it, the spring pressing the needles against the hook (fig. 279).

In close contact with the ulterior ends of the needles we find the card cylinder, a square roller, pitted with holes on the four faces at distances equal to the spaces between one needle and another. Gudgeons on the ends of the cylinder rest on open bearings, held by the ends of two long movable rods traversing the depth of the machine. Besides supporting the cylinder horizontally, it is the function of these two rods to impart lateral motion to the cylinder. A pair of slanted forks are secured upon the rods, and within the forks work a pair of bowls coming out from two vertical rods. The latter are important for other reasons. The rods terminate in a cross-head attached by link and pin to a lever, the crank of which is connected with the driving shaft of the loom. As the rods are lifted up

and down by the crank and lever, the bowls impart to the forks a lateral motion, and through them to the rods which act upon the cylinder. Rotary motion is given the cylinder by a hooked lever, fulcrumed on the framing of the dobby, the hook catching on to the lantern enclosing the cylinder as it moves outwards. The cards, punched with holes according to pattern, for each lifted shaft, are formed into a chain and hung upon the cylinder by means of small pegs.

The motion given to the vertical rods would seem to be too much trouble for the mere lateral movement of the cylinder; a simpler arrangement might have been adopted, if that were all. But the action of the vertical rods upon the cylinder is nothing more than the secondary use of a motion essentially necessary (fig. 280). Upon these rods depends the griffe, or lifting bar, slanted in towards the hooks, and placed so that its upper edge just touches on the hooks when they are in the vertical position. At every round of the loom crank—that is, at every pick of the loom—the rods lift the griffe. When the crank is at its lowest position, and the vertical rods are stationary, the cylinder brings its card up against the ends of the needles; all those needles the ends of which are opposed by solid cardboard are thrust back, sending the hooks held in the eyes of the needles out of the path of the griffe. The hooks having needles passing through holes in the cards remain in position; the rods draw up the griffe and lift the hooks, causing them to lift the heald shafts.

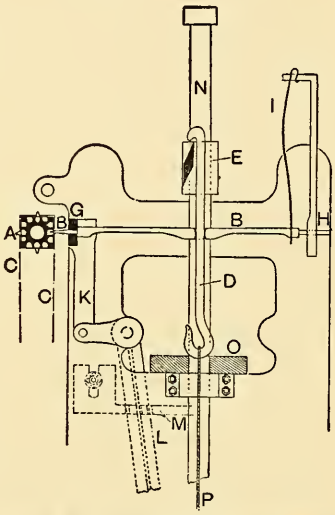


Fig. 280.—Jacquard Dobby: the Needles and Hooks

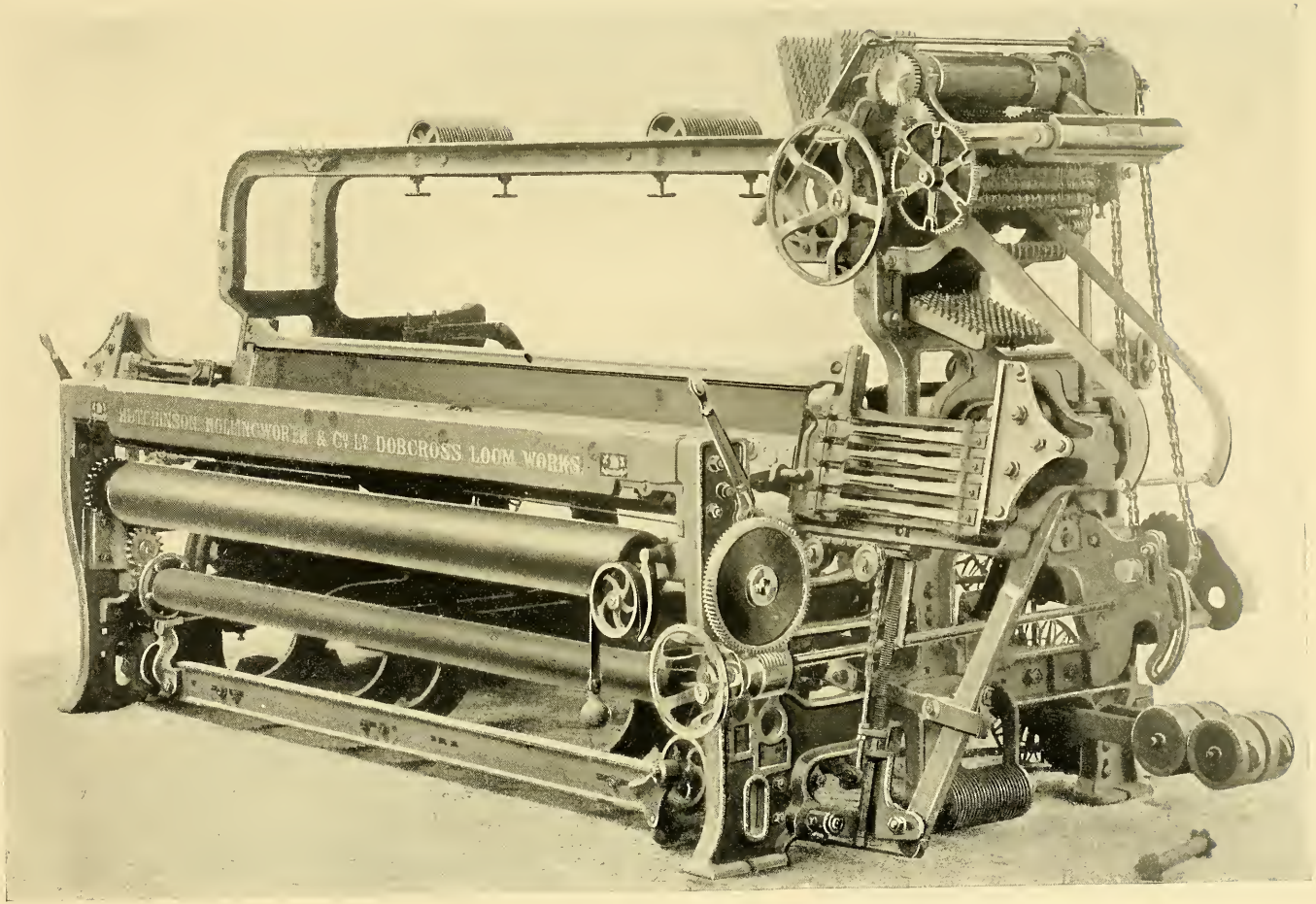
A, Cylinder. B, Needle. C, Cards. D, Hook. E, Griffe. G, H, Bearings of the needle. I, Spring. K, Slide for lifting or depressing the needle plate to the level of the upper or lower row of holes in the cylinder. L, Handle held in position by one or other of three grooves in the plate M. N, Upright bar actuating the griffe. O, Grid, on which the hooks rest. P, Cord supporting a heald shaft.

Various Dobbies.—As we have already stated, there are numerous dobby machines of various form and application. In all, however, the essentials are similar. Hooks and lifting bars or griffes, cylinders with cards or lags, needles or pegs media between cylinder and hooks, heald-shaft levers, and crank levers—the forms and methods of adjustment vary, but at bottom the principle at work is the same. Centre shed, double-lift, cross-border, the Blackburn, the Burnley, the closed-

shed and positive open-shed dobbies, in their several forms, exhibit such ingenuity as might tempt one to linger over their many intricate details. Having grasped the dobby principle, however, a weaver can easily acquire a working knowledge of almost any kind of the machine, with a few hours' studious and careful observation. Each form of dobby has its own defects, but the faults common to the class are excessive vibration, breakage of lags and needles, and the absence of an efficient detector of broken warp threads. Remedy of these defects has been constantly sought, with only partial success. At one end or another the leverage on the dobby must always be considerable; where the hooks directly lift the heald shafts, the lift and drop must be strong and heavy; where a shaft lever is employed, the vibration cannot be otherwise than extensive.

With all its defects, however, the dobby appliance is of immense service to textile manufacture. The compactness of the machine, the wide range of heald shafts it can control, and the directness of the relation between the pattern design and the heald shaft mechanism are qualities which place the dobby among the most useful of shedding appliances.

The American Dobby.—Many a machine, and mechanical ideas more numerous, have gone over the Atlantic, to return metamorphosed, made more directly acting, practical, useful. The genius of the American mechanic for adapting machines has become a proverb. An instance is what has been called the American shedding motion. This is the British dobby transformed into almost unrecognizable shape. Professor Beaumont has given a lucid and detailed description of the American dobby. "The object in the ordinary dobby and tappet shedding motions", he says, "is to lift and depress the heald shafts by a series of levers, but in the American invention it is to attain the same result by a system of pulleys. Instead of lifting and sinking the heddles by jack levers, they are, in this motion, drawn up or down by a number of pulleys. To each heald there are no fewer than three pulleys, two for elevating and one for depressing purposes. The principle of this shedding mechanism and the manner in which it lifts the leaves or shafts can be forcibly illustrated by passing a cord over a pulley rigidly fixed at any convenient height. Let one end of this cord be held in the hand some distance from and slightly above the pulley and a weight attached to the opposite end. The hand may be supposed to represent the jack lever and the weight the shaft. Now, if the former were drawn backward, or away from



HOLLINGWORTH & KNOWLES PATENT OPEN-SHED FAST-RUNNING LOOM
(AMERICAN DOBBY)

(Hutchinson, Hollingworth, & Co., Ltd., Dobcross)

the pulley, it would necessarily lift, or rather draw up, the weight, and this is exactly the kind of mechanical arrangement adopted in this machine in raising the healds. For example, a strap, in mounting the loom, having been attached to the upper portion of the jack lever, it is then passed over the pulleys, and fastened to the top of its proper heald shaft; so that if the jack is pulled backward it will elevate the heddle to which it is attached."

While aware that the American dobby is not alone in exhibiting

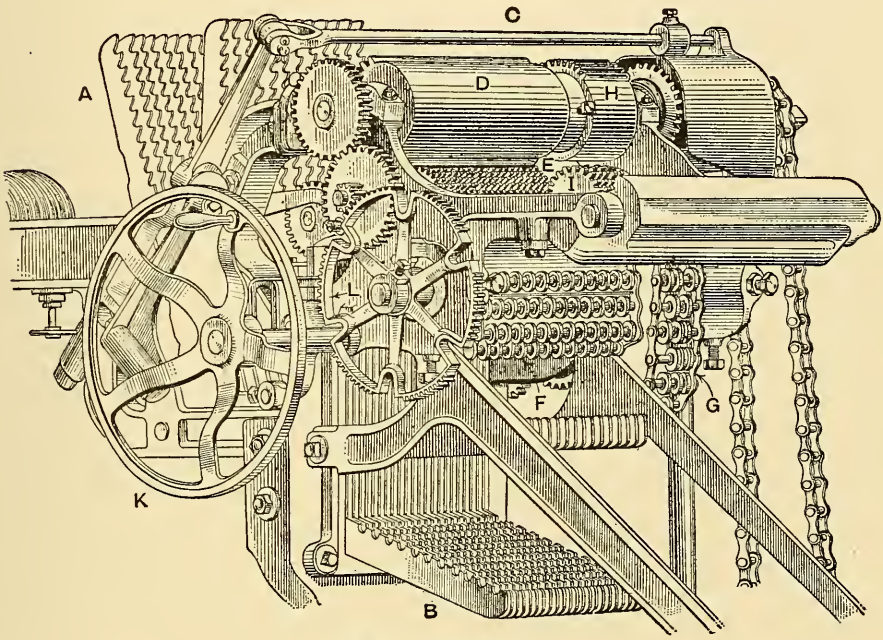


Fig. 281.—American Dobby

A, Harness jacks, lifting arms. B, Harness jacks, depressing arms. C, Lever of levelling handles. D, Upper segment cylinder. E, Gear wheels on vibrating levers. F, Pattern chain. G, Chain actuating shuttle motion. H, Segment wheel of shuttle motion. I, Segmented discs of shuttle motion. K, Hand wheel for turning motion. L, Driving wheel of barrel.

this principle, we need not deny that the application has some special features, and will repay study, not only because the American machine is interesting in itself, but also because it has come to stay in this country.

English and American Dobbies Contrasted.—The difference between English and American dobbies of this type is not one of small details merely, but of the whole structure. For lifting bars we have cylinder gears, for jacks there are vibrator levers, for lags, pulleys or bowls. The connection between the picking mechanism, also, is

closer on the American machine than it is on the dobby. Springs, needles, and top levers are conspicuously absent.

Cylinder Gears.—For operating the heald shafts the machine has a pair of cylinder gears, placed one above the other, the upper to lift and the lower to depress the healds. One half of the cylinders is in the form of a cog wheel. They are arranged to regulate the heald, shuttle box, picking motions, and taking-up motions, and are made in such a manner that the section which works the shafts is adjustable, admitting of the healds and boxes starting at different times; or the former a little in advance of the latter, in order that the shed may be changed previous to the picks or shoots of weft being driven home. This is a considerable improvement to a loom constructed on the open-shed principle, because, in such a machine, the lathe or batten leaving the piece before the shed has been altered by the engine, the pick or thread of weft last inserted is very liable to spring or fall back, this constituting one of the main causes why looms shedding on this principle do not generally admit of such heavy wefting as the closed shedding motion. The difficulty, however, is satisfactorily overcome in this loom by simply adjusting the heddle and box gearings on the cylinder to start operating on the vibrators at different times. Of course it will be understood that, whenever the toothed section of one cylinder is changed, it is necessary to make a similar alteration in the other.

The vibrator gears referred to are placed between the two cylinders, the latter capable of being transferred from the one to the other. When the upper cylinder engages the vibrator gear and levers, the heald shafts are lifted; when the lower cylinder comes into play, the heald shafts are sunk.

Vibrator Levers, Gears, and Connectors.—The vibrator plate is a toothed wheel, slotted half its inner circumference, riveted at the other side on the connector, and pivoted on the levers (fig. 282). The connector and vibrator lever extend at right angles from the plate. A pin limits the revolution of the vibrator plate by catching on the inner ends of the slot. In the event of the lower cylinder engaging the vibrator plate, the cogs on the former would gradually bring round the former to the end of its slot, which is half its revolution. This action would send the connector forward and lower the heald shaft to which it is attached.

The gentleness of this action contrasts strongly with the same operation on the ordinary dobby. We have noted, in examining the

various forms of dobby, that the lift of the hooks is swift and sharp, imposing some strain on the warp, and causing heavy vibrations; but here the lightest strain is at the beginning of the lift, or depression, greatest at the highest point of the lift, and slowly lessening to the end of the motion. The gain from this method is very obvious.

Harness Jacks.—Pinned on to the ends of the vibrators, the harness jacks transmit to the heald shafts the motions caused by the vibrator plate. Two-armed, one arm extending vertically to the heald shaft

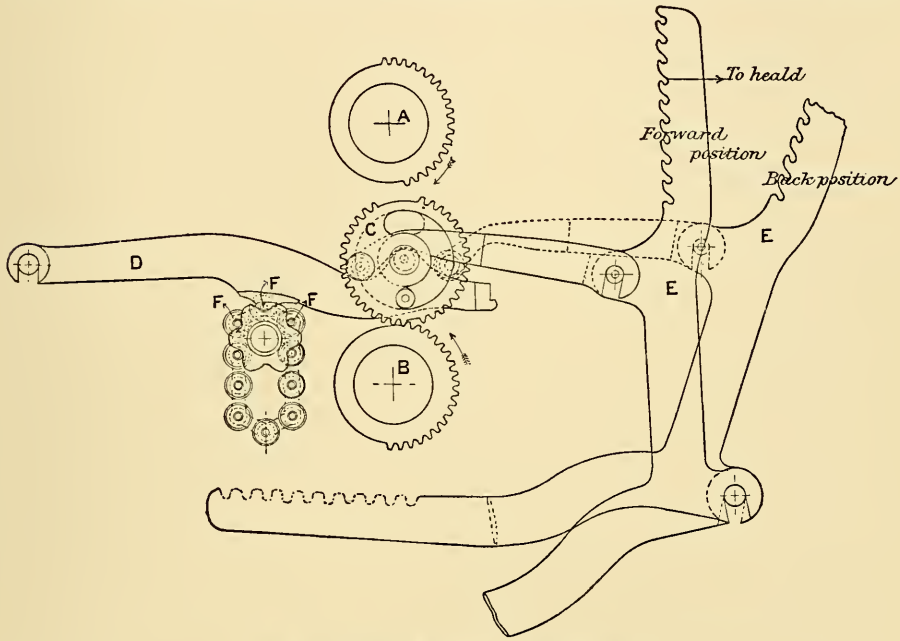


Fig. 282.—Driving Mechanism of American Dobby

A, Upper segment cylinder. B, Lower segment cylinder. C, Gear wheel on the vibrating lever. D, Vibrating arm acting on the griffe bars. E, E, Harness jacks. F, F, Chain on chain barrel

and the other horizontally, the vertical arm lifts and the horizontal arm depresses the healds.

Pattern Chain.—Like many another American device, this pattern chain has been borrowed from a British appliance already employed for other uses. It is nothing more than the tappet chain we have seen working on the chain tappets. Bowls, collars, and pin make up the chain, and they revolve on the barrel cylinder in precisely the same fashion. A bowl lifts and a collar depresses the heald shafts.

Pulleys and Jacks.—Over the heald shafts we find a pair of pulleys, and under them one pulley, with two-armed jacks. The upper and

lower parts are in reverse relation; in the first case, the jacks of the harness connected with the vibrator gear act on a pair of pulleys; in the latter case, one pulley acts upon a pair of jacks. The cords or wires from the harness jacks pass over the top pulleys on to the top shafts of the healds; similarly, the wires from the horizontal arms of the harness jacks pass round the bottom pulley and into the lower jacks which are connected by wires or cords with the bottom shaft of the healds.

Driving the American Dobby.—On the main crank shaft of the loom an upright shaft is geared by means of a pair of bevel wheels.

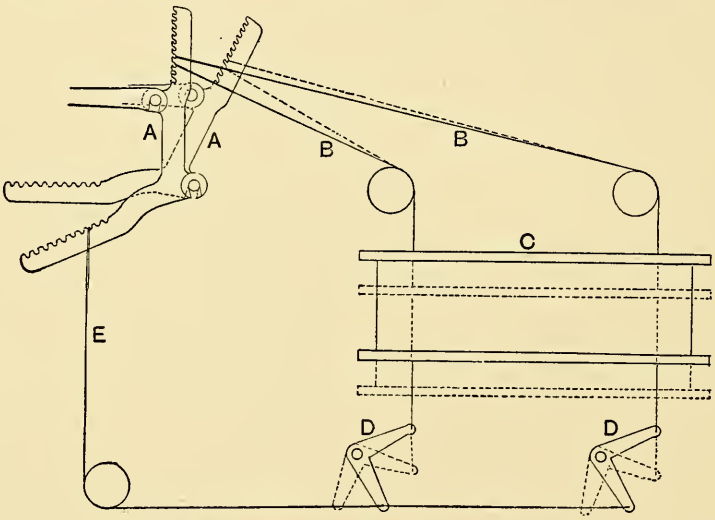


Fig. 283.—Shedding Mechanism of American Dobby

A, A, Jacks in forward and back positions. B, B, Harness cords. C, Heald. D, D, Elbow levers. E, Streamer.

From this shaft the cylinders are driven. On the lower cylinder shaft a pinion is fixed which gives motion to the pattern chain shaft. The whole machine is thus seen to be singularly united, all the motions being driven from one shaft. When either cylinder engages the vibrator plate, the latter imparts motion to the harness jacks and through them to the healds.

Shedding Action of the Dobby.—Let us now endeavour to view the whole action of the dobby (fig. 283). Suppose we elect to lift shaft No. 1. A bowl has come round on the pattern chain and lifted the vibrator into connection with the top cylinder, the teeth of the latter grip into the cogs of the vibrator, and cause it to revolve the whole length of the slot, drawing back the vibrator lever, and causing the

jack to lift heald shaft 1. While the vertical arm of the harness jack has been pulled back and away from the pulleys, the horizontal arm has been depressed; in consequence the cords on the lower pulley give way, and the jacks are free to lift up, thus letting the heald shaft rise freely.

Take a second case. Suppose the lower cylinder has engaged with the vibrator plate; it turns round from right to left and sends the harness jack forward. The upper arm of the harness jack is lowered, and therefore the under arm is elevated. The latter holds the cords round the lower pulley and the bottom jacks attached to the bottom heald shaft. Heald shaft 2 is therefore drawn down by the action of the bottom cords and sunk by the vibrator above. There is always the double action, the one helping the other.

Advantages of the American Dobby.—All the parts of this machine being positively connected, the motions correspond; a change in the shedding apparatus also involves a similar change in the shuttle-box motions. When turning back for a broken pick, the shuttle boxes, shedding and picking motions maintain their relations, so that the loom can be started again, after the error has been rectified, without the trouble of readjusting the shuttles to the pattern, and otherwise restoring the balance of the loom.

The American dobby is an open-shed machine. The motion is simply imparted by a holding-up bar acted upon by an eccentric cam on the end of the lower cylinder. When the shed is being formed, the eccentric acts upon the lock bar; this done, it is brought against the grate, and held there till the pattern chain brings round another link and changes the relations of the heald shafts. Another revolution of the eccentric repeats the motion.

Levelling the Shed.—One of the chief troubles the weaver has to meet in working an open shed is the difficulty of levelling the shed when a warp thread has broken. Fully alive to the problem, the makers of the American dobby have solved it in an ingenious way. Under the front end of the vibrator levers what is called the *evener slide* has been fixed. Drawing out the slide, the weaver lifts all the vibrator gears above the level of the lower cylinder, and naturally into contact with the upper cylinder. By turning the upper cylinder, he levels all the shafts and obtains an even warp. Removing the slide, the operator restores all the shafts to their normal positions.

Mechanical Character of Dobby Work.—As compared with the tappet, the dobby mechanism makes slight calls upon the ingenuity and

attention of the weaver. Here are few problems to solve, such as we considered in relation to the tappet. Understanding of the machine undoubtedly helps the operator; but it is greatly beyond his control. A dobby is a fixed mechanical quantity, and it may be either good or bad, well devised or otherwise, but allowing the weaver little say in the matter. The persons chiefly concerned in the machine are the designer and the mechanic; the weaver is brought by the dobby nearer to the position of the mere machine minder. He sees that it works properly, or as well as the nature of the contrivance allows.

CHAPTER VI

The Jacquard

The Jacquard.—Everybody has heard of the Jacquard. To many persons it is a mysterious appliance with which weavers make fancy fabrics otherwise impossible; to young weavers it is the tool which they desire most of all to manipulate. An atmosphere of magic has gathered round this loom mounting. Perhaps the curious name with which it has been labelled has helped to promote the air of mystery; the name conveys nothing. Had it been called the hook-and-needle harness, it is probable that more than half the mystery would have been dispelled. "Jacquard" is the name of a Frenchman who suffered a great deal in his efforts to bring the appliance into practical use.

Joseph Marie Jacquard.—Born at Lyons in 1752, the son of a manufacturer, Joseph Marie Jacquard was apprenticed by his father to the weaving trade, in order that he might succeed him in the business, though the lad showed a marked dislike of the weaving shed and all that pertained to it. Thus confined by parental authority, his restless disposition found vent in mechanical experiments. His aim at first was to devise a machine which would weave lace netting, the basis of many of the richest French laces. Defeated in all his attempts, Jacquard then turned attention to the higher branches of his own trade. How much credit is due to him for the development of the appliance which bears his name, nowhere clearly appears. According to M. de Fortis, the author of a *Life* of Jacquard, he transformed what had previously been merely a curious toy into a practical tool; but the facts do not bear out the biographer's contention. As early as 1728 an inventor named Falcon had made a machine which is practically identical with

the Jacquard at present in use, in all but the cylinder or prism. Moreover, we find that M. Vaucanson invented a machine, in 1746, six years before Jacquard was born, which was practicable in every respect, containing all the parts of the modern Jacquard. The weakness of Vaucanson's invention consisted in the employment of perforated paper bands passed round a perforated cylinder; but the cards which Jacquard applied instead had been invented by Falcon many years before. At this distance of time it is impossible to say how much of Jacquard's work was original and accidentally coincident, or how much he was indebted to his predecessors.

If Jacquard was not original as an inventor, he was an innovator, and suffered as such. When, in the year 1804, he introduced the loom mounting now known by his name, into his factory, the silk weavers of Lyons strenuously opposed him. The Conseil des Prudhommes, a body appointed to safeguard the trading interests of the town, took possession of his machine, carried it to the public square of Lyons, and there publicly destroyed it. Branded as an enemy of the commonweal, Jacquard laboured on through difficulty for many years, though Napoleon gave him a small pension upon which to live.

Perhaps the persecution of Jacquard helped more to bring the loom mounting into general use than the special merits of the special form he had attempted to introduce. It is significant that neither the marvellous ingenuity of Falcon nor the high repute of Vaucanson had commended the contrivance to the weaving trade; but after Jacquard's adventures became known, the machine made its way over France and across the Channel into Great Britain with great rapidity. Before Jacquard's death, in 1834, the appliance was very well known among us, chiefly as a substitute for the drawboy on the harness loom. Adding immensely to the productiveness of the harness loom, the Jacquard encountered some opposition from the hand-loom weavers in Paisley and elsewhere; but the economic gain was too obvious to be ignored, and the draw loom passed out of use before it. During the nineteenth century the Jacquard was considerably altered and improved by British mechanics. It was adapted to the power loom, and given many various forms specially suited for different classes of loom and methods of weaving. At present the range of the Jacquard extends over nearly the whole of textile industry. It performs equally upon the lace loom and the carpet loom, upon the swiftest power looms and the finest silk hand looms. To the linen weaver, not less than to the weaver of figured gauzes, the Jacquard has been of very great service.

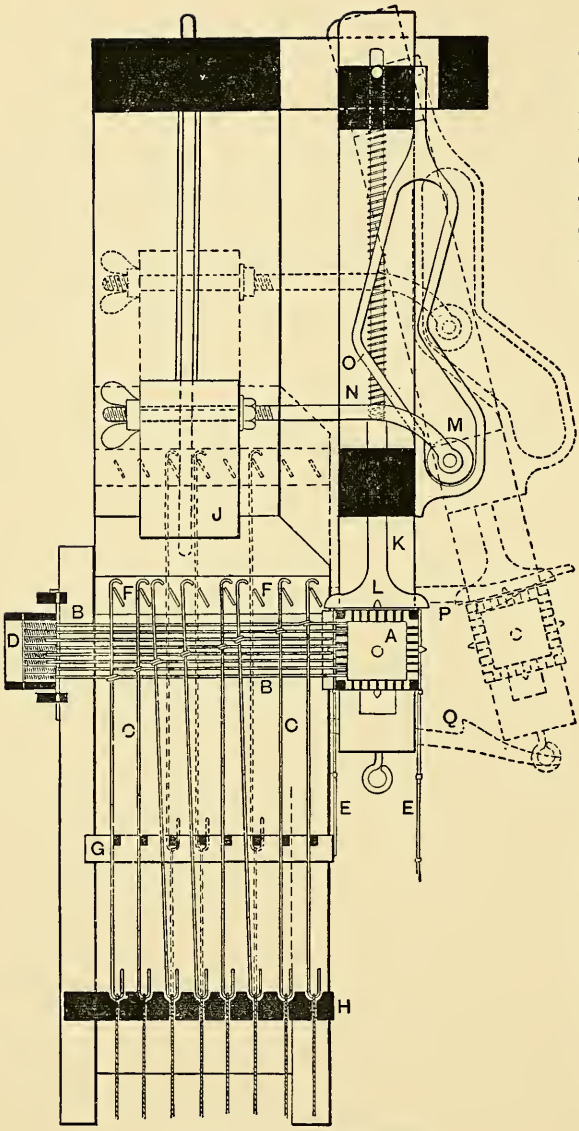


Fig. 284.—Jacquard Mechanism

A, Cylinder. B, Needles. C, Hooks. D, Springs to keep the needles in contact with the cylinder. E, Cards. F, Griffe knives. G, Grid. H, Bottom board. J, Griffe block. K, Arm, carrying the cylinder. L, Hammer, having a spring on its shank to steady the cylinder. M, Bowl on the end of a lever N attached to the griffe block, and giving motion to the cylinder arm by means of the swan neck O. P and Q are catches on the prongs of a fork whose office is to turn the cylinder as it recedes.

Parts of the Jacquard.—Every Jacquard machine contains griffe, hooks, needles, heel rack, card cylinder or prism, and cards. The difference between one form of the machine and another consists in the mechanisms which apply these parts. Before going on to examine the principal methods of application, it is advisable to make ourselves thoroughly acquainted with the form and function of each part. Having built up the mechanism piece by piece, we shall be able to comprehend its working readily.

Hooks.—Formed of iron wire, the hooks are bent at both ends, the upper end being curved into a shallow hook sufficient to grip on to the lifting griffe, while the lower end is a hook about 1½ in. long, because designed to hold securely the heald or neck-heald cord of the warp. The size of the Jacquard is determined by the number of hooks it contains. Some authorities classify the sizes of Jacquard according to the number of needles contained. It seems to us simpler and more direct to refer to hooks,

because, in tying up, we have to think of the number of hooks available, not the number of needles, of which there may be two or more to every hook. The designer, however, may answer that he thinks first of the number of needles at his disposal in framing his design. As may be perceived, the matter is slight and not to be dogmatically dealt with.

The bottom ends of the hooks rest upon a board the surface of which is sunk to receive the curved heads of the hooks, and perforated to let the harness cords linked on to the hooks through when in rest; the heads of the hooks hold into the edges of a series of knives, named the *griffe*. A short space under the griffe, the hooks pass through the eyes of needles placed horizontally across them. Hooks are ranged in rows of eight or twelve, in ordinary Jacquards, though the arrangement may be varied for special purposes. In common phrase, we speak of a 200, 300, 400, 600, or 1200 Jacquard; but in numbers which are not a multiple of either eight or twelve, the number of hooks do not exactly correspond to the term given. For example, a 200 Jacquard with hooks ranged in rows of 8 would have exactly 26 rows; but if the hooks are ranged in rows of 12, there are 204 hooks ranged in 17 rows. Several reasons can be given for this difference; but as the argument would take us beyond the simple details of Jacquard structure, discussion may be deferred till all the parts have been examined.

Needles.—A needle is made of round wire, straight at one end and made into a long loop at the other. The eye is on the body of the wire. The position of the eye depends wholly upon what row of hooks the hook it holds occupies. Say that we have twelve rows of hooks, then the eyes of the needles will be formed in twelve different places. If a space of 0.27 in. separates one row of hooks from the next, the eyes of the needles holding the second row of hooks will be 0.27 in. farther along the body of the needles. The same space will separate the needle eyes of each successive row of hooks. In this machine the eyes on the needles holding the first row of hooks will be 3.24 in. from the eyes of the needles on the last row.

If the needles cross the rows of hooks vertically and in the direction of the regular sizes, then there must be several needles on the same plane, because, as we have supposed, there are 26 hooks in the depth of the 8-rowed Jacquard of 200 hooks and 17 in the 12-rowed one. Now here we see one of the reasons why the sets of hooks must be made up to a certain number over the nominal number of the machine. The way in which they are grouped is shown in the following table :—

Hooks.		Rows.		Needle Tiers.		Needles.
100	.....	4 by 26	.....	4	.....	104
200	.....	4 ,, 51	.....	4	.....	204
200	.....	8 ,, 26	.....	8	.....	208
300	.....	6 ,, 51	.....	6	.....	306
300	.....	8 ,, 38	.....	8	.....	304
300	.....	12 ,, 26	.....	12	.....	312
400	.....	8 ,, 51	.....	8	.....	408
500	.....	8 ,, 63	.....	8	.....	504
600	.....	12 ,, 51	.....	12	.....	612

The arrangement of the needles in tiers constitutes another problem in regard to the hooks. A needle on the lower tier holds its hook on a lower level than a needle on the top tier; the difference in leverage amounts to a considerable proportion when the hooks are short. As a rule the difference is obviated by placing the hooks governed by the higher tier of needles at distances apart graduated according to the height of the tiers. On long hooks the proportion of difference is so slight as to be negligible, and all the hooks are therefore placed at equal distances from each other.

It should be clearly understood that the hooks are separated from each other transversely and longitudinally. In the one case the space is 0.27 in., and in the other something less than 1 inch.

Heel Rack.—The looped ends of each vertical row or tier of needles are passed through a stout framing, called the *heel rack*. Behind the heel rack is a strong iron pin which passes through all the loops of a tier of needles. Obviously the pin prevents the needles from moving either to or fro farther than the length of the loop. At the rear ends of the needles is fixed a box of springs, a spring to each needle. Set in the box to move on a horizontal line only, these springs rest against the needle ends, yielding to what pressure may be put upon the other ends of the needles, and always sending them back again to the normal position as soon as the pressure has been removed.

The pointed ends of the needles protrude through what is called the *needle board* to the outside, a length of from $\frac{1}{8}$ in. to $\frac{1}{2}$ in. On some Jacquards the needle board is of wood, and on others it is an iron plate; but in all cases it is drilled with holes to correspond with the holes in the cylinder or prism without.

Griffe.—The lifting knives of the Jacquard are carried by a block, technically named the *griffe block*, the whole apparatus, including the knives, being called the *griffe*. Two thin iron plates are bolted to the block, and through both plates as many narrow slits as there are rows of

hooks are punched to a depth of about an inch in a diagonal direction. Knives of strong hoop iron, with feather edges, and perforated with holes at proper intervals, are secured to the plates by strong wires passed through the plates and the knives. The position of the knives is slightly angular, and over the heads of the hooks. If the knives were vertical, the curved heads of the hooks would be broken as they descended to lift again. When the hooks are vertical, the knives catch into them; the action of the pattern-forming apparatus, therefore, must be tilting the hooks back out of the range of the knives. That this negative mode of action is the best we shall presently see.

Cylinder or Prism.—Outside the framing which holds the hooks, needles, and griffe, but geared so that it may come into contact with the ends of the needles protruding through the needle board, is the cylinder or prism. This is commonly square, but it may be made hexagonal or octagonal if necessary. Each face of the prism is pierced with holes about ½ in. in depth, at distances corresponding to the spaces separating the needles in the Jacquard. For every needle there must be a hole in the cylinder, drilled in such a manner that the needle will not touch the wood. On the outer edges of each face of the prism tapering wooden pegs stand up, to hold the chain of cards in position. To help the pegs and give facility to the movement of the cards, two flat springs sit on the outer edge, and two wire springs on the inner faces of the cylinder. From both ends of the cylinder a gudgeon protrudes, supporting the cylinder upon bearings in the framing containing it. To protect the cylinder and afford a base for the action of the driving mechanism, a metal lantern is fastened on each end, the rounded corners covering the corners of the cylinder, but the middle parts curving in from the edges to a depth of about ½ in.

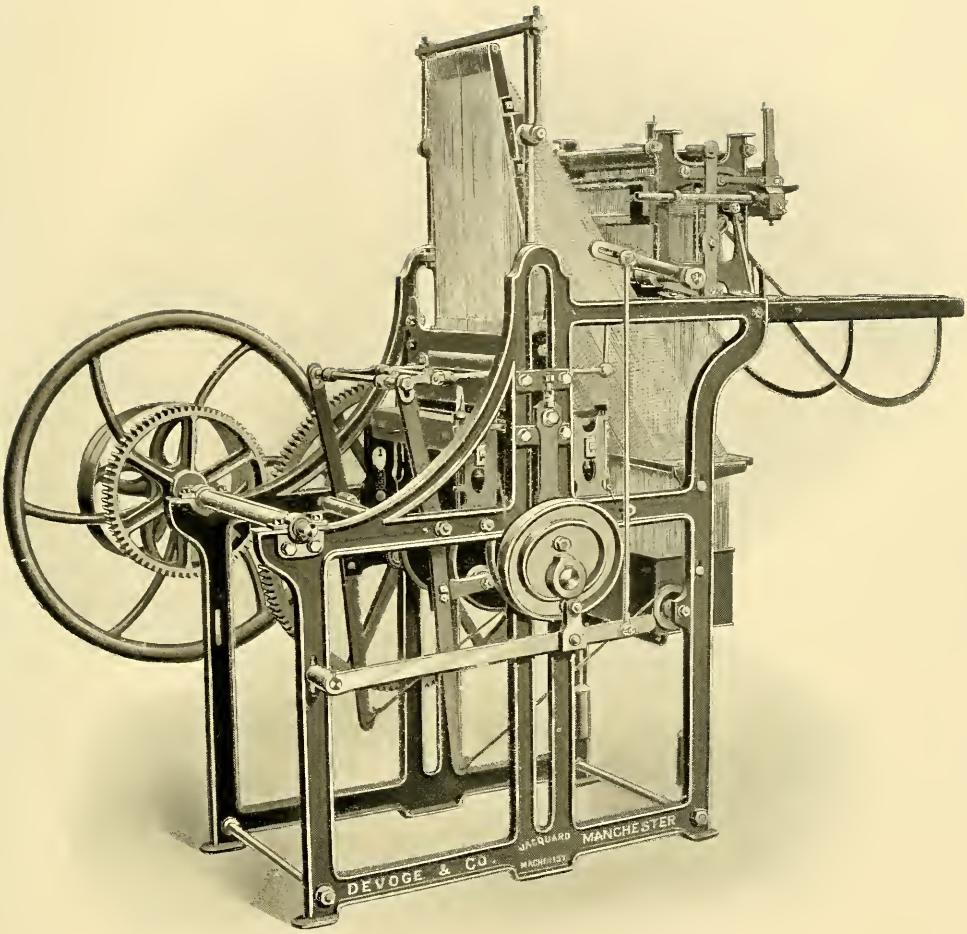
Cards.—Upon the Jacquard cylinder an endless chain of cards is hung. The cards are laced together in the order prescribed by the pattern. As they come off the cylinder, the cards are caught in a cradle formed of two pieces of curved iron secured beneath the cylinder. The first cards to fall are pushed back by those which follow, and the order of succession is maintained, the rearmost card being the first to rise on to the cylinder.

The common length of a card is 16½ in., and the breadth ranges from 2½ to 3½ in., according to the number of hooks and needles in the machine. Being designed to push out of the path of the knives those hooks not called into action, the cards must be of some strength and weight. As we have hinted, the holes in the cards correspond to

the warp threads which the designer intends to be flushed, letting through the needle ends, which in consequence are powerless to take the hooks out of the upward path of the knives on the griffe. The hooks are lifted, therefore, at what we may describe as the bidding of the cards.

Card Cutting and Lacing.—Our present business is not with any form of design, but it is impossible to understand the functions of cards without some general notion of the method of the designer in preparing his patterns for the Jacquard loom. The designer takes a piece of paper ruled into squares, the vertical lines being supposed to constitute the warp threads, while the horizontal lines are regarded as weft. This is not always true, but we may take it as correct for our present purpose. For every warp thread which he intends to be flushed in the cloth the designer makes a black square; all the white squares on that line indicate that the warp is not to appear. When the designer has dealt with as many squares as there are needles in the short rows of the Jacquard, he draws a thick line vertically on the paper. For a similar purpose he draws a thick horizontal line, forming a larger square of the small squares. Having completed his whole design, the artist hands his work over to the card cutter. For the commoner classes of designs, pointed paper is supplied by manufacturers ruled in large and small squares. Designers select those "counts" of paper suitable for the patterns.

As might be expected, the ingenuity which contrived the Jacquard shedding appliance found the devising of a card-cutting machine an easy task. The early workers, however, did not attach much importance to the saving of time in the operation; they regarded it as an artistic operation to be delicately done. Hence they employed ingenious and efficient hand tools. After all our great mechanical progress these hand tools are still largely employed. The handicraft card cutter has for his tools a pair of hinged plates, a plate with a double handle, a box of punches, and a roller press. Laying the two-handled plate on the bench, with the design before him, he inserts into the holes of the plate one punch after another, in accordance with the design. Having placed all the punches correctly, the card cutter takes up a blank card, and places it evenly in between the two plates hinged on each other. Then, by means of sliding catches, he secures the plates, and fixes the two-handled plate containing the punches over the whole. The combined plates he pushes in under the roller of the press, and punches the holes in the card. No finer cards are to be seen than those produced by this process.



READING-IN AND REPEATER CARD-CUTTING MACHINE

(Devoge & Co., Manchester)

Card-cutting Machines.—Mechanical invention left the hand card cutter but a little while alone in his province. The first efforts of the inventor were directed to making the hand-cutting operation automatic; but the gain in saving of time and labour effected by that form of machine barely justified its existence. Not until some ingenious man conceived the notion of adapting the Jacquard machine itself to the work of card cutting was the position of the handicraftsman seriously threatened. This idea served a double purpose. Not only have cards to be cut for new designs, but cards of old designs rapidly wear out. At the present day the reproduction of cards is the more important branch of the card-cutting business. Hence the value of what are called *reading-in and repeater machines*. Many machinists have entered into this field, and they play numerous variations upon the common theme. At the risk of seeming to ignore admirable ingenuity, we must restrict our examination to the simplest principles of the two distinct varieties of card-cutting machines, the one on the Jacquard principle and the other on the piano model.

Reader-in and Repeater.—At the back of the machine is a roller into which a set of 612 cords are fastened; the cords are extended vertically and looped through a guide board, the loops being hung in a series of wire hooks. To the upper ends of the 612 wire hooks another set of cords are tied, passing in loop fashion through a horizontal frame, and up over a roller, then down through another board on the other side, the ends of the cords being weighed by a lingoe tied to each. Midway between the roller and the board, we find another set of cords, each one spliced on to the second set of cords. This third set of cords is led over two guide rods, through a comber board, and the ends attached to lingoes. From every weight on the ends of the third set of cords a cord is carried through another hole in the comber board and passed up over a glass rod at right angles from the line of the depending cords. Drawn forward, the cords are run through a perforated iron plate, and attached to the end hooks of horizontal needles. Other two perforated plates, riveted in a horizontal plate over them, form bearings for the needles which protrude through the front plate, their points standing out. On the middle of the needle, and between the front and second plate, is a spiral spring, the end of which rests against the second plate, a neck on the needle curbing the other end. In front of the needles is fixed a box containing punches fitting the needles in the machine. The punches have spiral springs upon them, and in front of the punches is the plate for the cards.

When starting to work this machine, the card cutter fits a comb on to the first set of vertical cords, the teeth of the comb dividing the cords into sets of threads corresponding to the number of vertical squares contained in each division on the design paper. Then two lease rods are put through the cords to separate them into odd and even threads. Laying the design before him, with a straight-edge under the first line of squares, to assist his eye, the card cutter proceeds to weave cords across the lines of vertical cord, placing the crossings in front or behind the vertical cords, according as the design required a lifted or a sunk warp thread. The design completed, he inserts a roller into the position occupied by the top cord. By the pressure of an attached treadle, the cords in front of the roller are deflected, and the punches corresponding driven through the card. The next cross cord is removed, and the roller again inserted in its place; so the whole of the cards are punched.

When all the cards have been made, and it is desired to obtain others of the same pattern, a 600-hook Jacquard is placed over the third comber board, and connecting cords led from the hooks to the cords on the machine. The cards already made are laced and hung on the prism of the Jacquard. The hooks of the Jacquard, directed by the cards on the prism, lift those cords which are intended to produce perforations in the cards on the plate. The weight of the lingoe being taken away, the springs of the needles hooked on to the cords so lifted send the points of the needles forward to pierce the card. In this manner the cards are automatically reproduced.

Improved Machines.—The machine above described is not now made, though many are still in use. The newer machines, of which the apparatus fitted to the Single-lift Jacquard (fig. 285) is a good example, have better methods of arranging and manipulating the punches; but these are merely mechanical details which affect in no way the essential principles of the contrivance.

Piano Card Cutters.—Naturally desirous of a compact and directly controlled card cutter, machinists have hit on the idea of utilizing that piano movement which has become so useful in type-writing, type-setting, and other machines. Upon a long iron table the whole of the principal parts of the machine are carried (fig. 286). From the table two uprights support the pattern board, fitted with straight-edges movable by screws to any line of the design pinned on the pattern board. A pair of plates are bolted firmly along the front of the table—a space between them sufficient to let in a card of ordinary thickness. At each side of the plates a spindle passes through, the spindles

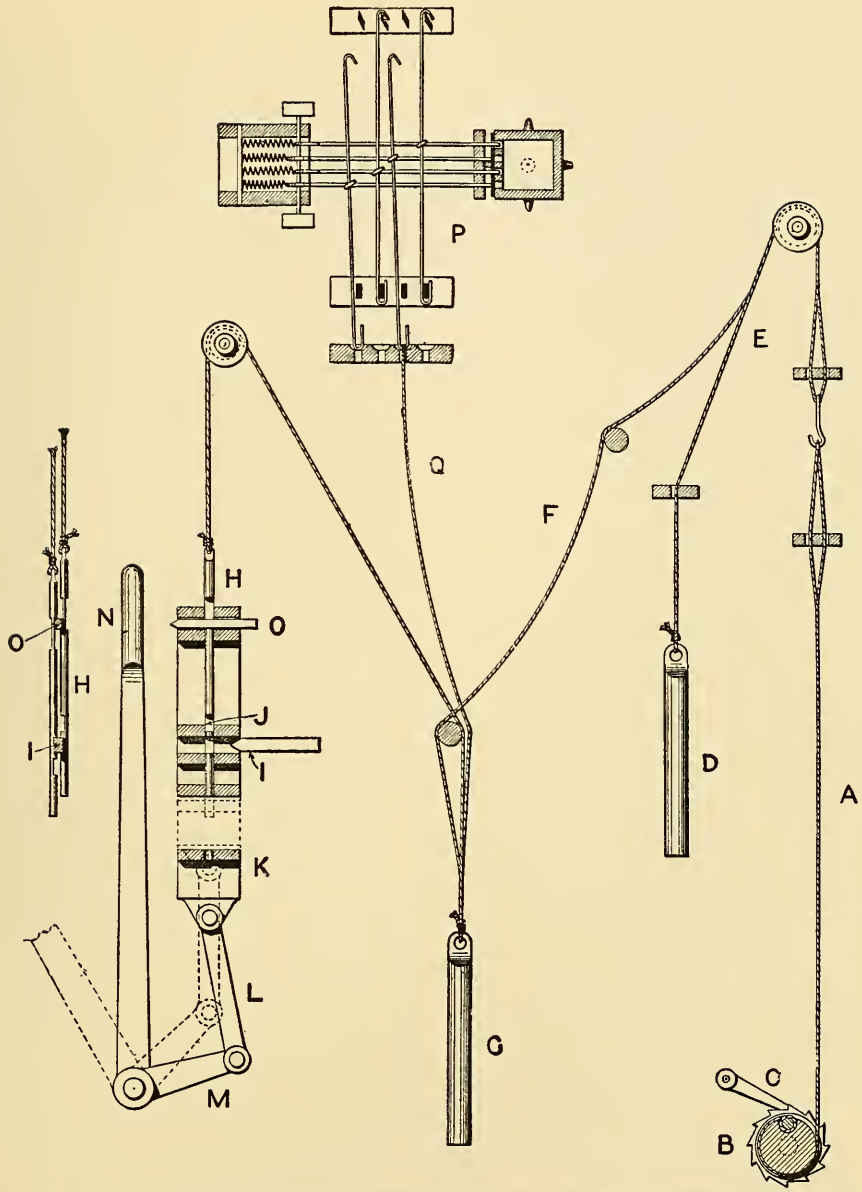


Fig. 285.—Diagram of Reading-in and Repeating Card-cutting Machine with Single-lift Jacquard

A, Vertical draw cords. B, Draw-cord roller. C, Pawl. D, Lingoe on draw cords. E, Splice of third set of cords on to second set. F, Third set of cords attached to cords of punches. G, Lingoe weighting cords. H, Punches. I, Sliding comb. J, Slot in punch. K, Plate for cards. L, Lever forcing plate against punches. M, Arm of lever. N, Handle. O, Punch-holding comb. P, Jacquard for repeater. Q, Cord connecting Jacquard with lingoe G, the lift of the Jacquard releasing the punches from the drag of G.

supporting the headpiece containing the keys and punches. The headpiece is literally the chief part of the whole machine, and merits

close attention (fig. 287). The headpiece is a double plate slotted and drilled for the keys to pass through. Thirteen keys, with square shanks and oblong heads, pass through the plates, and upon the shanks between the plates spiral springs are wound. In the centre,

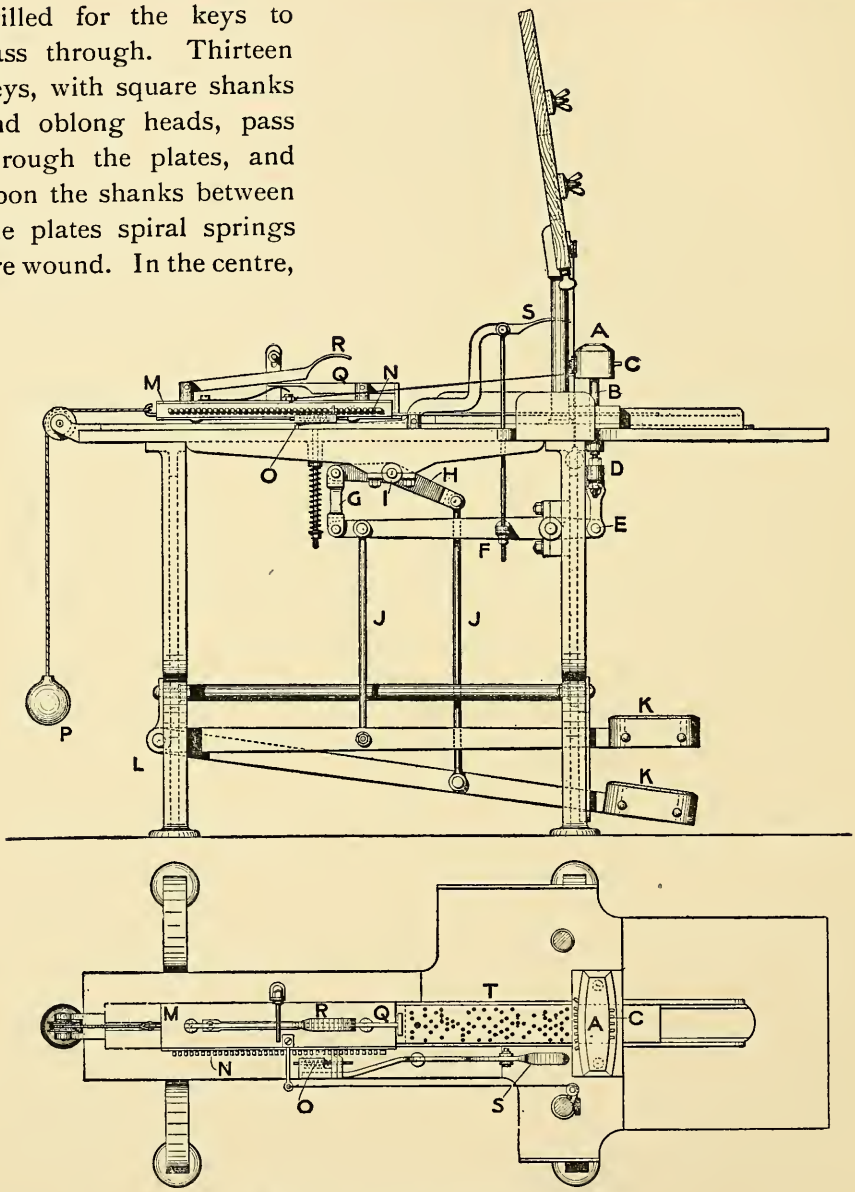
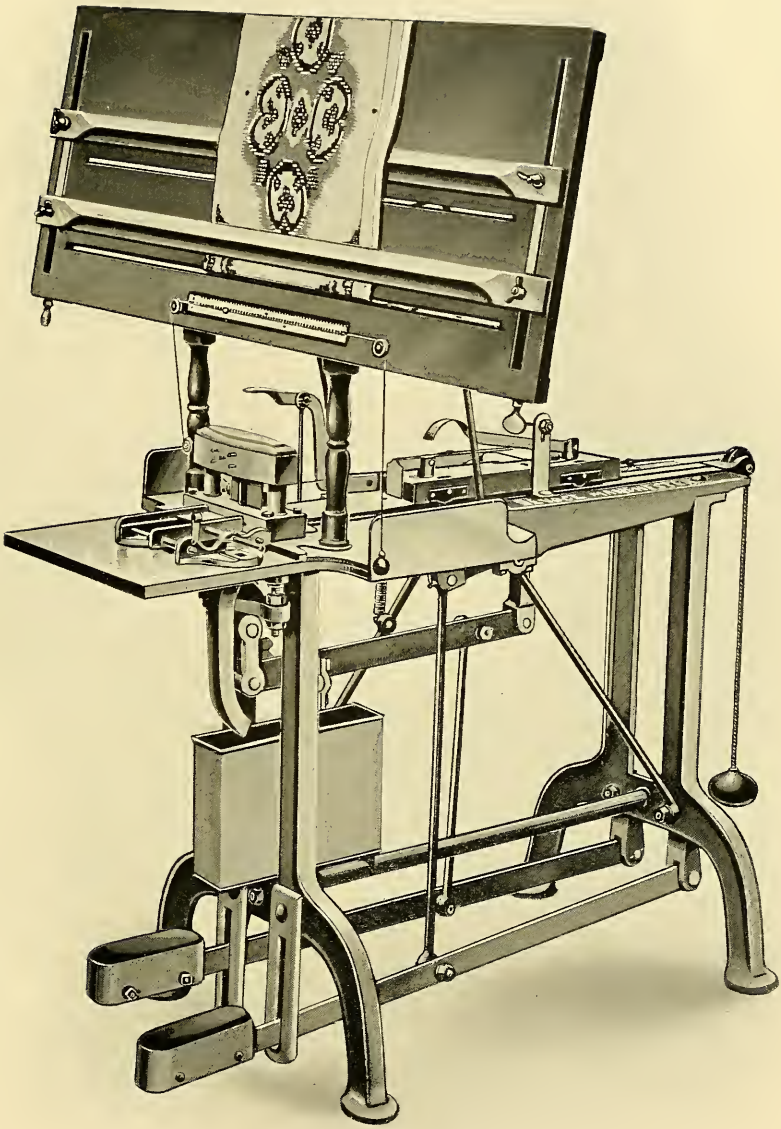


Fig. 286.—"Piano" Cutter: Side Elevation and Plan

A, Headstock. B, Spindles. C, Puncher. D, Lock-nut of crosshead. E, Pin. F, Centre lever. G, Link. H, Three-armed lever. I, Fulcrum of lever. J J, Connecting rods. K K, Treadles. L, Fulcrum of treadles. M, Carriage. N, Pins of rack. O, Slip catch. P, Weight. Q, Nipper of card. R, Lever. S, Handle of lever. T, Card.

under the ends of the keys, there are twelve small punches, with flat heads and square shoulders, fitted to the gauge of Jacquard prism or



PIANO CARD-CUTTING MACHINE

(Devoge & Co., Manchester)

cylinder. Under the thirteenth key is a thicker punch, designed to make the holes for the cylinder pegs. The heads of the punches are carried in a plate attached to the headpiece, and may be lifted clear out of touch with the plates enclosing the card; but when the headpiece is lowered for a stroke, all the punches rest on the card. Only those punches, however, which are struck by the keys pierce the card.

The headpiece is lowered and lifted in this way. The two supporting spindles are fastened to a cross-head under the table, which connects through levers to a three-armed lever; from two arms of this lever the shafts of the treadles of the machine depend (see Plate). Having placed a card in position under the plates, the operator puts his foot on the right treadle and draws down the headpiece. Reading from the pattern what punches are to pierce the cards, he strikes the keys; the keys drive down the punches thus placed in trim, and a card is perforated in one row of its breadth. It is to be noted that this machine is limited to twelve rows of holes, and that therefore it can only strike as many holes as may be in the depth of the card. We have now to find what method and machinery have been contrived to perforate the whole width of the card with accuracy.

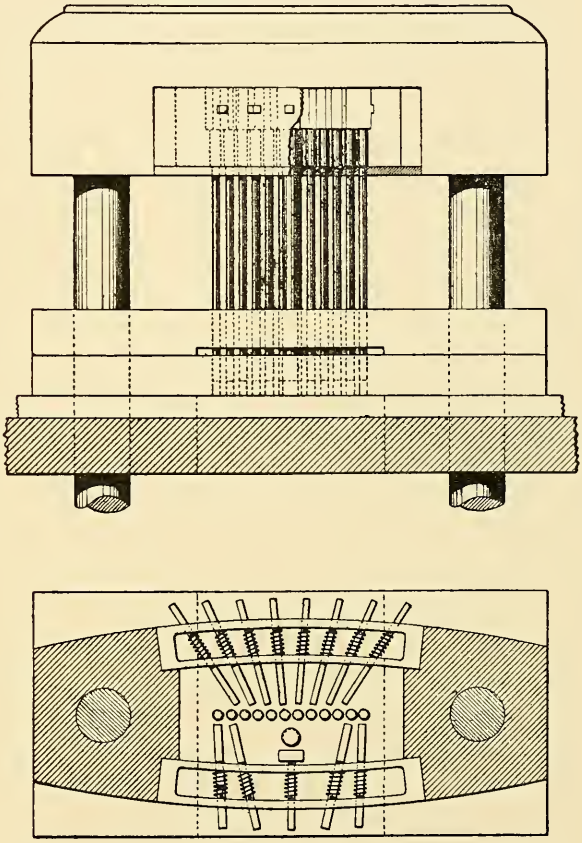


Fig. 287.—Front Elevation and Sectional Plan of Headstock for "Piano" Card Cutter. Scale four times that of fig. 286

Immediately behind the double plate above noted we find a clip, which grips on to the end of the card as soon as it is inserted (fig. 286, plan). This clip extends from a flat carriage on the back of the table,

borne upon rails under its wheels. Along one side of the carriage a rack of pins is fixed, the pins being equal in pitch to the spaces between the Jacquard needles. Into the rack a slip catch gears, the shaft of the slip catch passing down through the table and into connection with the levers of the second, or left-hand, treadle. On the shaft a helical spring is wound to hold it down. A weight attached to the end of the carriage acts as the drawing force. After the card has been punched the operator elevates the headpiece by depressing the left treadle. At the same time the treadle lifts the slip catch vertically. The slip catch is double, one side higher than the other, the lower one being kept in advance by the spring. When the catch is lifted the lower of the two teeth is left in the rack; but the weight at the end of the carriage overcomes its spring, and causes it to lose grip. The carriage, therefore, moves forwards one tooth of the rack, drawing with it the card held in the clip attached. Thus every lift of the headpiece brings the card into position for another row of holes to be punched.

In the hands of an expert operator the piano card cutter produces with great rapidity. That the punches should be operated automatically is admittedly desirable, but we have not seen any appliance which accomplishes the purpose satisfactorily.

Card Lacing.—The machinists have presented the trade with a large variety of lacing machines, most of which closely resemble the common household sewing machine. To describe any one of these would be superfluous. The great bulk of lacing is still performed by hand, though some of the newer machines are quite efficient.

Mechanism Operating the Cylinder or Prism.—We have obtained the cards, and the next business is to use them. The endless chain of cards is laid within the cradle of the cylinder, the first card lying on the face of the prism turned toward the ends of the needles. On the common Jacquard two methods of operating the cylinder have been adopted, and manufacturers are free to choose which they prefer. The first and older method is to operate the cylinder from the griffe block. By the second method the cylinder is driven independently. Each has its advantages and comparative disadvantages.

Working Cylinder from the Griffe Block.—The whole cylinder rests upon bearings supported by screws on the end of a batten, the screws permitting the position of the cylinder to be changed either up or down to suit the other parts of the Jacquard (fig. 288). The batten hangs from brackets projecting from the upper part of the loom, the

centre pins affording free swinging motion. Screwed to the upper and lower rails of the batten a metal swan neck forms the curved groove in which the bowl from the shaft connected with the griffe block works. Prongs on the end of the shaft hold the bowl between them, and the other end of the shaft is threaded through the griffe block, the projecting part being fixed on the other side of the block by a lock and wing nuts. The length of the shaft is adjustable by the screw threads and the nuts. That part of the shaft which lies within the block is square, to prevent the possibility of turning.

As the griffe block lifts it carries with it the shaft of the bowl in the swan neck on the batten of the cylinder. Following the curves of the swan neck, the bowl imparts to the cylinder a to-and-fro motion, alternately bringing forward to, and pushing away from, the ends of the needles in the Jacquard.

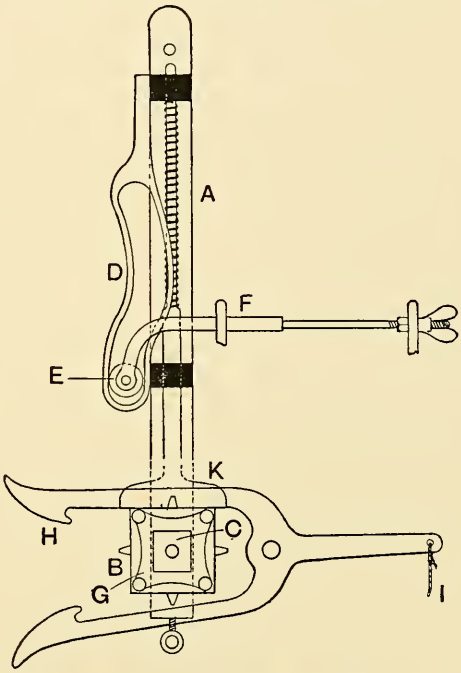


Fig. 288.—Method of Operating Cylinder of Jacquard from the Griffe

A, Batten of cylinder. B, Card cylinder. C, Bearings of cylinder. D, Swan-neck guide. E, Bowl of griffe-rod. F, Rod from griffe-block. G, Lantern on end of cylinder. H, Upper fork. I, Cord for reversing motion of cylinder. K, Head of hammer steadying the revolving action of cylinder.

More necessary to the working of the cards is the rotary motion of the cylinder. On this form of machine the method of imparting the rotary motion is very simple. Upon a pin in the machine frame a double-pronged fork, wide enough to enclose the whole cylinder and the lantern enclosing it, swings freely. The upper prong of the fork rests against the top side of the lantern, while the lower prong is hung clear all the time the cylinder revolves in one direction; when the cylinder is swung out by the action of the shaft in the griffe block the edges of the lantern come in contact with the hooked end of the upper fork prong. Catching in the corner thus presented, the prong gives the cylinder a turn. Having no further opportunity, the fork only gives the cylinder one-fourth of a revolution. Counteracting the force of the action of the prong, which might other-

wise send the cylinder farther round than exactly the length required, two hammers rest upon the upper face of the cylinder. These hammers are carried in the batten of the cylinder, and upon their shafts loose springs are wound. The force of the impact of the fork prong sends the hammers away, but the springs bring them back again, and the broad heads steady the cylinder, while preventing it from going farther round.

Rotating the Cylinder Independently.—Some difficulty has been encountered in timing the stroke of the needles to the lowest point of the knives when the cylinder is operated from the griffe block. If the knives have not quite cleared all the hooks when the cylinder strikes the cards upon the needles, the hooks will resist the impact and tear the cards. A very slight derangement of the swan neck would be sufficient to cause the fault to occur, and it is so serious that the risk should be avoided if possible. The most obvious resort is to work the cylinder independently and time it to the griffe. With that view Mr. J. Bullough, in 1842, patented "a certain arrangement or application of mechanism, whereby the card cylinder is made to turn entirely independent of the lifting motion for the shedding of the warp". In 1855 Messrs. Wooller & Butterfield, Bradford, added improvements, and in some factories their machine is still employed. As it appears in that shape, however, we recognize in it a crudeness quite below the standard of mechanics set at the present day. Machinists have greatly improved upon that contrivance, though adopting the ideas of inventors more philosophical than they could claim to be. An eccentric cam is fixed on the main shaft of the loom, and from it a shaft is attached to a cranked lever, to the upper arm of which the pair of rods holding the card cylinder are pinned. The eccentric shaft imparts a horizontal movement to the rods and the cylinder with every turn of the loom crank shaft, and brings the cards forward to the needles at the proper moment, independent of the lift of the griffe (fig. 289).

The rotary movement of the cylinder is equally independent, and exhibits a feature of special interest. Upon one of the cylinder rods bearings for a small shaft are mounted. Into this shaft a key is fitted to grip into the groove cut in the boss of a bevel wheel placed upon the shaft, the object being to prevent the bevel wheel from partaking of the sliding motion of the rod to which the shaft is fixed, while preserving the rotary connection between the wheel and the shaft. A further precaution to maintain the rigidity of the bevel wheel is a

groove cut in the outside of its boss, into which the end of a bracket firmly bolted on the loom frame inserts itself. At the other end of the small shaft a collar carrying a crank pin is fitted. From the end of the card cylinder comes out a star wheel, bearing against the collar on the shaft, and turned by the crank pin catching into the notches between its points. The bevel wheel, shaft, collar, and cylinder are driven through the agency of a bevel on the end of a vertical shaft, which in turn receives power from a horizontal shaft gearing into a

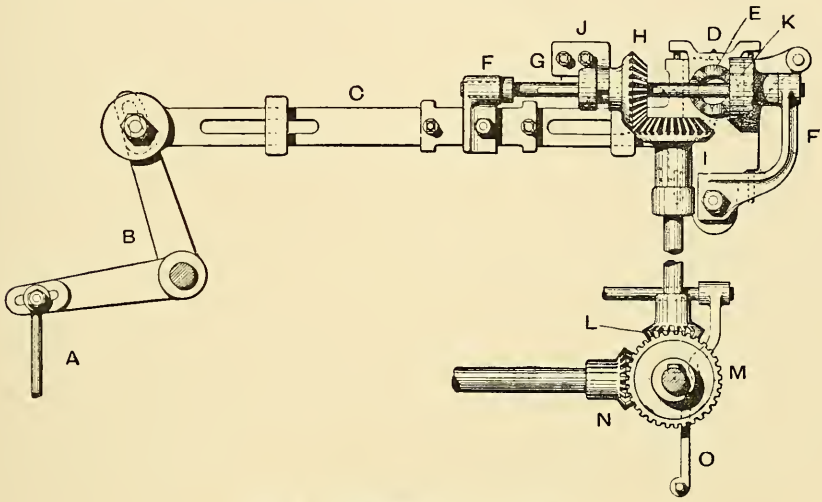


Fig. 289.—Independent Cylinder Jacquard

A, Connecting rod of eccentric cam. B, Cranked lever. C, Sliding rod carrying the cylinder D, the star-wheel E, and the bearings F F of a rod G which drives the bevel-wheel H. J is a bracket carrying a finger fitting a ring-groove on H, preventing it from sliding with the rod G to which it is loosely keyed. K is a collar mounted on G, and carrying a pin which operates the star-wheel E, and through it the cylinder. The bevel-wheel H, and with it the collar K, is driven by means of the gearing L, M, N, and I, of which M can be thrown out of gear and another bevel-wheel on the same shaft brought into operation by means of the lever O, thus reversing the motion of D.

bevel wheel on its lower end. This horizontal shaft may be driven from any suitable part of the loom.

An integral part of the original invention upon which this set of appliances has been based was a reversing motion, enabling the weaver to turn back the complex Jacquard to remedy a defect with accuracy, ease, and certainty. The device has been incorporated in this mechanism by a simple arrangement of duplicate bevel wheels, either of which may be engaged with the driving wheel. By touching a lever the operator can transfer the gearing from the one to the other, and reverse the whole movement.

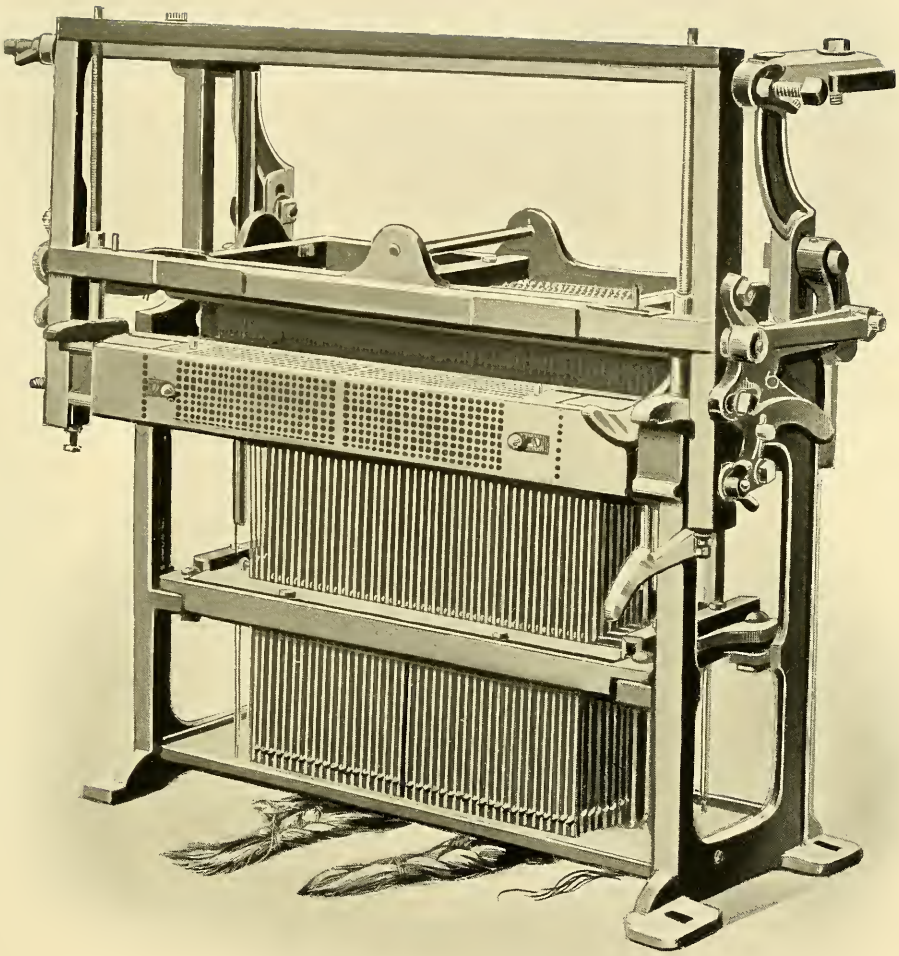
The Single-lift Jacquard.—Having built up the single-lift Jacquard, we are now in a position to observe its action with clear understanding

(see Plate). The lever on the loom shaft has brought the griffe block down to its lowest point, the knives about ½ in. below the curved heads of the hooks. By the descent of the block the bowl shaft working in the swan neck on the batten of the cylinder has drawn the latter forward. A card perforated according to pattern sits on the cylinder face and impinges against the ends of the needles, sending out of the straight line all those hooks for which no hole has been pierced. Continuing to revolve, the loom crank causes the lever to lift up the griffe block, the knives attached to it catching into the hooks which stand vertical, drawing them up. Neck cords from the warp are fastened to the lower ends of the hooks, and therefore rise when they are lifted, forming the required shed on the warp below. As soon as the griffe has lifted the knives clear above the heads of the hooks left down, the cylinder, again under the control of the bowl on the end of the shaft screwed in the head of the griffe block, swings out from the needle board. Actuated by the springs in the spring box at the other end, the needles resume their normal position, bringing those hooks missed to the vertical attitude. The griffe ascends still farther to form the proper width of shed, and the cylinder swings out. Near the end of its course the cylinder encounters the curved break of the one prong of the double fork enclosing it, and, the corner being caught by the iron projection, the cylinder is given a quarter revolution, carrying round a fresh card.

Waiting on a mechanism so complex, the picker of the loom cannot travel at high speed. Ninety picks per minute is a fairly good average for looms governed by the single-lift Jacquard; but for many cotton, silk, and wool fabrics we do not desire a greater speed than about eighty picks per minute.

It may seem that the warp connections have been forgotten; but that subject also belongs to other Jacquards, and the problems involved must be dealt with in whole.

Striving for Speed.—After all the arguments in favour of a slow-speed Jacquard have been adduced, the manufacturer leaves them unanswered and demands speed. Rapid production may or may not be artistic, or otherwise good, but it economizes both capital and labour. The greater the turnover on the capital invested, and the smaller the amount of labour time consumed, the greater the profit. We do not speak of the manner in which the profit is divided: the manufacturer may get the whole of it; he may be compelled to share it with the buying public; by the same agency the manufacturer may be forced



SINGLE-LIFT JACQUARD

(Devoge & Co., Manchester)

to hand over the whole gain to the public, selling the goods at a lower price, equal to the economy effected; but the profit is there. Hence the constant demand for speedier and ever speedier machines in all branches of industry.

A single-lift Jacquard acts only upon that part of the warp which it elevates. The whole of the shed is therefore formed by the lift; upon the hooks rests the whole burden of the shed. The main disadvantages said to accrue from this are: 1, The speed of the loom must be kept slow, to give time for the shed to be formed; 2, the strain upon the hooks, and through them upon the loom, is heavy; 3, the stress of the lift upon the warp is excessive, and causes many broken threads and many more stressed threads, which tell in the wear of the fabric. The other side of the argument has been hinted, and the continued adherence of the majority of practical men to the single-lift machine renders long debate needless; but the disadvantages stated are admittedly real and worth redressing.

The remedy seems obviously to lie in the production of a double-lift Jacquard. In 1849 Mr. Barlow took out a patent for a Jacquard "with double counterpoised griffes and apparatus for simultaneously raising different portions of the suspended wires of such apparatus". Barlow's machine contained two sets of hooks opposed to each other, one set of suspending wires coupled to the hooks at points separated by a distance equal to the height of the lift, two sets of needles, two sets of cards, and two cylinders. Each set of hooks was acted upon by separate griffes acting alternately.

Complex as this machine was, it contained a good idea. The double lift was shown to be quite practicable. By reverting to the common form of hook, and substituting two neck cords for the suspending wire, Mr. Barlow brought his machine into a measure of popularity which has not been entirely eclipsed even to this day.

Another attempt of minor importance was the patent taken out by Mr. J. Craven, of Bradford, in 1857, for "giving independent motion to the bottom or knot board, in order that a downward motion may be given thereto at the time of giving upward motion to the lifting blades to form the shed". To quote further from the specification, "The ordinary lifting frame and the bottom knot board are operated by separate levers and cranks or other means, capable of being shifted or timed to vary the times of operating the parts in relation to each other as desired". Such a motion, as may be readily perceived, would divide the shedding equally between the lifting and the sinking hooks.

Ainley's Jacquard.—In 1876 Mr. Ainley, of Huddersfield, patented a form of Jacquard which has been of great service to weavers of fancy woollens, worsted mantle, and cotton cloths. The main improvement shown in this machine is the simultaneous depression of the bottom board with the lifting of the griffe block. From the loom crank shaft a lever operates a quadrant overhanging the centre of the griffe block, to which it is attached by a strong strap or cord. From the exterior end of the quadrant lever a shaft depends vertically to another lever attached by a shaft to the base of the bottom board. Spindles from the griffe frame slide into brackets on both sides of the bottom board, to keep it steady. When the griffe is lifted the outer end of the lever raising it lowers, sending the shaft downwards. As the latter controls the bottom board, it descends, drawing down all those hooks which have not been caught in the knives of the griffe. As the griffe again descends, it draws up the bottom board and closes the shed (fig. 290).

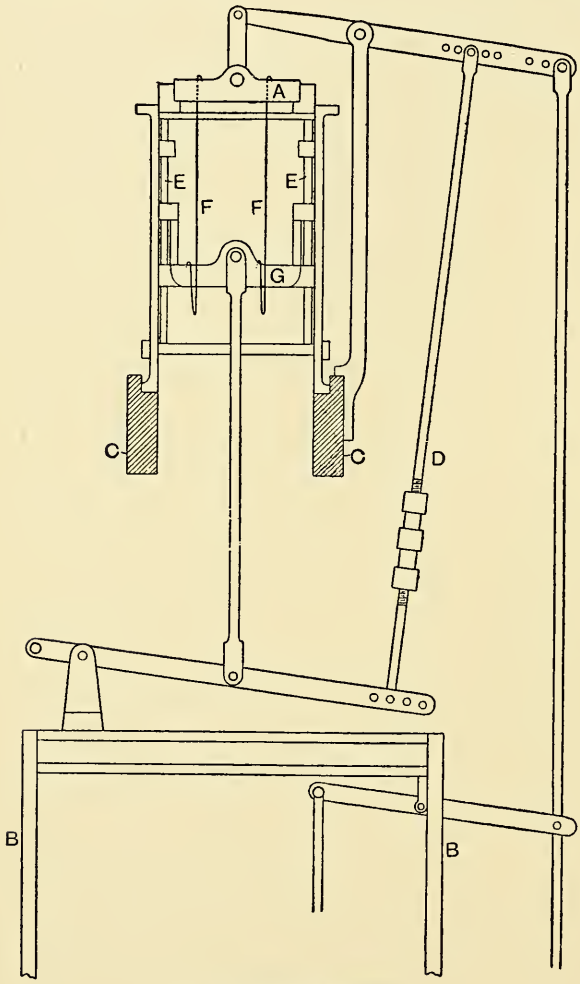


Fig. 290.—Ainley's Jacquard

A and G, Griffes. B B End framing of loom. C C, Main beams. D, Adjustable connecting rod. E, Guides. F, Vertical hooks.

The Crossley Jacquard.—The original Crossley Jacquard was patented in 1854; but that form of the machine has long since been discarded in favour of improved Jacquards operating on the same

principle. The main idea consists in the employment of double hooks and two lifting griffes, with one card cylinder. In structure the two griffes differ slightly from those on the single-lift Jacquard. No. 1 griffe, as we may designate it, is formed of iron plates similarly shaped to those of the ordinary machines; but the plates on griffe No. 2 are deeper and wider in the slots, because it must allow room for the knives of its complementary as well as its own. The double hooks are 16 in. long and protrude over 4 in. below the supporting grid or bottom board. The rows of hooks are scarcely 1 in. apart, and the contiguous rows are coupled by two neck cords joined about 9 in. below the bottom board. Another feature of note is the needles (fig. 292), each one of which grips into two hooks.

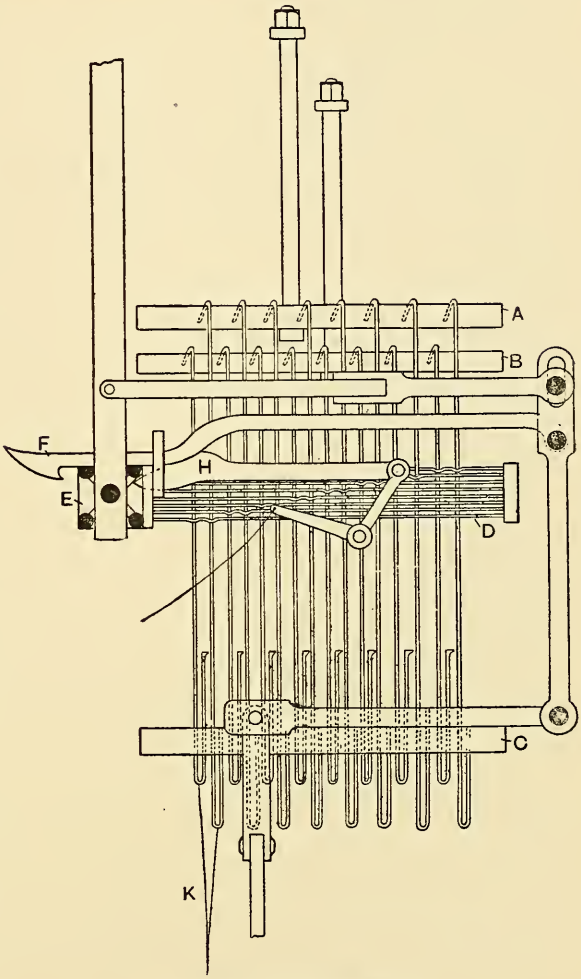


Fig. 291.—Crossley's Jacquard

A, B, Griffe frames. C, Grid. D, Needles. E, Cylinder actuating needles. F, Catch driving cylinder E forward. H, Catch for pulling E back by hand. K, Neck cords.

Like many of the newer Jacquards, the cylinder of this machine is driven direct from the main driving shaft. Taken together, the levers form a broken square, terminating in a vertical lever which moves the card cylinder to and from

Fig. 292.—Crossley's Jacquard Needle

the points of the needles. On the vertical lever, passing up the other side of the machine, a horizontal lever is pinned, having a slight curve in the middle downward to the top of the needle board, and a hook on its end. The hook lies over the card cylinder, and at every outward lift catches on one of the corners and gives it the required quarter turn.

Connected with the curved lever is a hand crank which enables the weaver to reverse the motion of the cylinder when anything has gone wrong. The cord attached to the crank is within easy reach of the weaver.

When one griffe is up the other is down; as the two prepare to return, a card is pressed against the extremities of the needles. A pair of hooks are left vertical by a hole in the card, and the ascending griffe lifts one of them. But suppose the next card pushes against the same needle; it acts on the hook formerly left down through the hook already up. This imposes strain on both needles and hooks, as well as on the card. The length and flexibility of the hooks, and the light hold on the lower ends by the grid, serve to mitigate the defect; but the cards on this Jacquard always wear out more quickly than those on an ordinary machine.

Joined by the neck cords on to one thread, the hooks act in pairs. Given that a warp thread is to be lifted twice in succession, the hook that has first lifted it descends and lets the thread come with it. The second hook is rising, truly, but the neck cord on that side has been slackened, and before the lifting hook has made the cord tight it can have no effect on the warp. By that time the descending hook has come down to the level of the lifting one, and there is therefore no contradiction between them. Of course, when the position of the warp thread is to be reversed, the ascending knife does not touch the hooks.

A practical writer thus summarizes the Crossley Jacquard: "There are many points of difficulty in dealing with this machine, but they are such as can be overcome with proper care and skill in setting the machine. In the first place, the card cylinder must be brought into contact with the needles at each pick, or on the descent of each of the griffes; therefore its movements must be very rapid, and it can only be kept in contact with the needles for a very brief period, and its timing must be very accurate. The change of hooks from one griffe to the other taking place at the moment when they are passing each other, the cylinder must be in contact with, and pressing,

the needles exactly at that instant and no other; for if a little before, or a little after, the change would fail to take place, and the pattern would be destroyed; so that every care must be exercised in the adjustment, and every part must be strong and rigid enough to keep its place when adjusted, or trouble will ensue. The stability of the parts is no doubt a matter for the makers to consider, but those having charge of the machines cannot be too careful in paying attention to the matter, and if they find the working is often going wrong, they may readily find out where the weak place is, and strengthen or remedy it.

"The next point is also one which calls for all the care of those in charge of the looms. In consequence of the rapid movement of the card cylinder it turns so quickly that the cards are very liable to be thrown off the pegs which keep them in position. And, once thrown off, the result is often very disastrous; for not only is the pattern destroyed, but the cards are often torn, and must be repaired; and there is probably nothing more aggravating to the weaver than the constant necessity of repairing cards, because it is troublesome, worrying work, and involves a considerable loss of time. Here, again, the stability of the working parts of the machine is an important factor, as the least vibration in the arms carrying the card cylinder is quite sufficient to cause infinite trouble, and vibration may be communicated through any of the connecting rods, should they happen to be too weak or slender. Too much care and attention cannot be bestowed upon this portion of the mechanism, and, should any fault occur, the sooner the weak part is found and remedied the better.

"The arrangement of the springs for keeping the cards in place on the cylinder, though often looked upon as a minor matter, is of no small importance, their strength and proper adjustment requiring both skill and care. If they are too strong, or not properly adjusted, they are liable to tear the cards, more especially if the cards have been carelessly laced together—an occurrence not uncommon. And if, on the other hand, they are too weak, they will allow the cards to "jump" off the pegs, and then come tearing and disaster. So that, on the whole, this apparently trifling matter in the details of the machine may become a very serious source of trouble if not carefully looked after. In the Jacquard, as in many other machines, it is the series of trifles which go to make up a successful working whole." Another authority, criticizing this description, says: "Hooks

never change from one griffe to the other. A fresh selection is made when one griffe is at the top and the other at the bottom; at this time the cylinder must be pressing a card against the needles."

Double-lift, Double-cylinder Jacquards.—From the point of view of the theorist the double-lift, double-cylinder Jacquard is the best.

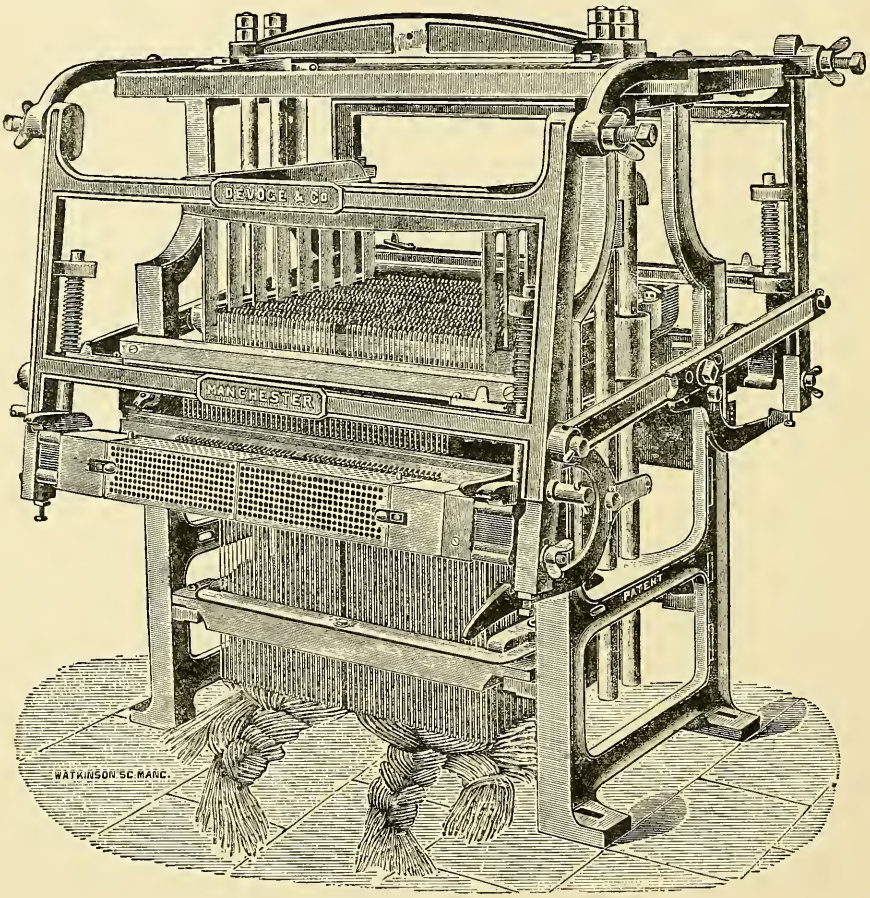


Fig. 293.—Double-lift, Double-cylinder Jacquard

It is swiftest and strains the warp least. But the worker has also some right to an opinion on the matter, and from his point of view that form of Jacquard is a nuisance. First, the cards are divided into odd and even picks, or odd and even warp threads; the cylinders, therefore, must strike alternately, with the cards in perfect order. But on high-speed machines a card may stick for the fraction of a second, and the order of sequence is lost. Other troubles of a like nature constantly occur with double-cylinder machines. This Jacquard

is nothing more than a single-lift made double, and detailed examination of it is hardly necessary. The hooks of the two sets face each other, and the card cylinders are at opposite sides of the machine.

Various Jacquards. — Ingenuity inexhaustible continues to be lavished on the Jacquard. Hooks, needles, card cylinders, driving and controlling mechanisms, are changed in form and position, to obtain one advantage or another. Some aim at economy of cards, others at reducing the number of needles and hooks. There are open-shed, cross-border, and compound Jacquards in vast variety. But, after all, the essential principles of the machine remain practically unaffected. If the warp threads are to be lifted, some form of hook, or cord, or other similar instrument must perform the act, and be directed by either card cylinder or some other appliance equally efficient.

Gauze Jacquards.—Special applications of the Jacquard to the production of certain fabrics must be considered. A slight difficulty occurs in this connection. We have purposely confined attention wholly to the machine itself, and left out of account the harness which it controls. Any other method would have involved us in complications almost inextricable. Certain forms of Jacquard, however, are conditioned by the harness connections. One among these is the gauze Jacquard.

When dealing with the heald shafts, we fully explained the nature of gauze healding and the doup heald which is the special feature of that loom. Following upon that, we explained the common harness. The terms employed, therefore, in describing a gauze Jacquard cannot be wholly unintelligible to our readers.

A Jacquard may be used to weave a simple gauze pattern, but the most common practice is to employ healds only for that purpose, and reserve the Jacquard for figuring. The problems special to gauze Jacquard weaving are these: 1, To manage the doup heald so that it will operate in proper order, as though it were upon an ordinary heald-shaft mechanism; 2, to regulate the action of the easing appliance so that it will always come into play at the right moment; 3, to combine the figure with the plain gauze.

The Jacquard patented by Messrs. W. & H. A. Fielding in 1890 is a very serviceable machine, and may be taken as typical of the class. In this machine we find a set of ten griffe bars for lifting the hooks of the harness, and two griffe bars for operating the easing appliance of the warp (fig. 294). The needles working the latter are also attached

to the doup heald and the standard. The neck cords of the easing hooks do not pass directly to the warp, but are attached to short and adjustable levers, fulcrumed at the farther ends upon a horizontal bar in the loom. From each lever the cords descend to the warp and take through the mails they carry the odd or crossing threads. These mails are about $1\frac{1}{2}$ in. below the mails of the figuring

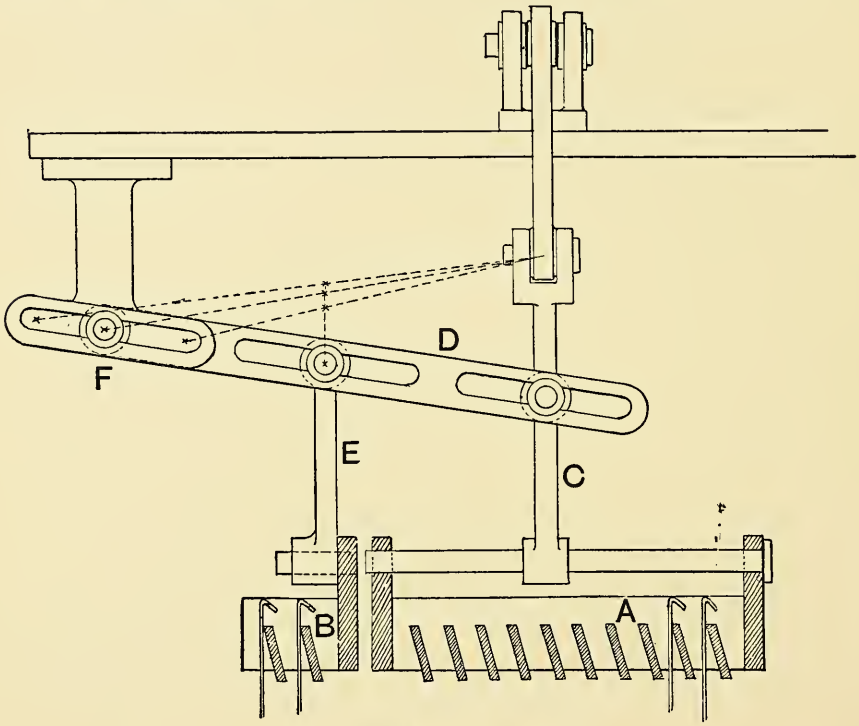


Fig. 294.—Lifting Motion of Gauze Jacquard

A, Figure griffe. B, Slackening griffe. C, Rod lifting the figure griffe. D, Slotted lever lifting the slackening griffe by means of the connecting rod E. F, The fulcrum on which the slotted lever rocks.

harness. Heavy lingoes are required for the ends of the easing cords, because there is no other way of providing an elastic tension for restoring the crossing threads to the normal level. Upon a machine of 600 hooks there are 104 easers in each repeat. To aid in keeping the warp threads at tension, two thin rollers are placed under the warp, one on each side of the point where the mails of the easing cords hold it, constituting the bridge (fig. 295).

Placed at a distance of from 10 to 12 in. in front of the easing cords, the figuring harness is formed upon the common principle. All those warp threads which perform the same function in the pattern

are passed through mails in cords which are joined together in neck cords, and hung upon one hook of the Jacquard. While the figuring threads of the warp only pass through the mails on the figuring harness, the crossing threads are passed pair by pair through the cords of the easing harness, singly through cords in the figuring appliance, and then, after passing in pairs again under the figuring warp, they are drawn through the loop of the doup heald slip.

So far as the making of gauze cloth is concerned this apparatus differs very little from the operation of the simpler heald-shaft motion. When a cross shed is being formed, the standard heald lifts, carrying with it the slip heald, and requiring the easing harness to slacken the warp threads sufficiently to allow the movement to be performed. In

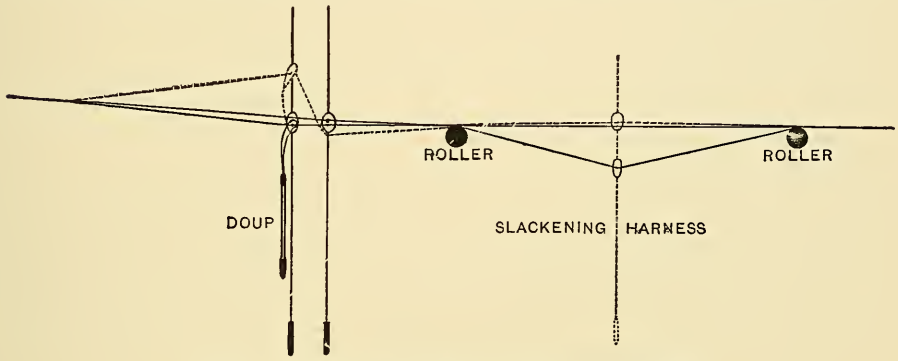


Fig. 295.—Gauze Jacquard: Diagram of Slackening Arrangement

weaving figure, the half heald lifts with the rest of the warp; or when no crossing is to be made, the half heald operates so that it may neutralize the existence of the standard altogether. In this case the crossing threads are merely ordinary parts of the warp, and may be lifted or depressed as the cards on the Jacquard cylinder direct.

Application of the principles detailed may be varied to a wide extent. For several reasons what is called the doup-heald formation may be adopted. This involves some changes in the relative positions of the healds, but nothing beyond the obvious. Again, many patterns require two or more doup slips. These and other variations, however, can best be worked out in practice; they are practical devices, and affect in no way the essential principles of gauze weaving with the figuring Jacquard.

Plush or Carpet Jacquards.—We have hitherto been looking at Jacquards working with hooks. Perhaps the reader has become so accustomed to those appliances that a Jacquard without them is almost

unthinkable; but there is one branch of the textile industry in which Jacquards are employed which have no hooks. We ought, perhaps, to say that Jacquards without hooks have been applied even to those cloths commonly operated by the machines described; but such applications are exceptional and scarcely to be regarded seriously. In the weaving of plush fabrics, however, including all kinds of velvets and several kinds of carpet, the hookless Jacquard is very common. As we already know, these fabrics are formed of two separate warps, the one ground and the other pile. The ground warps are generally operated by heald tappets, and may therefore be left out of account meanwhile. The Jacquard appliance is the object upon which attention must be directed.

A Typical Pile-fabric Jacquard.—One of the best forms of this class of Jacquard is that which works the Brussels carpet loom (fig. 296 *a*, *b*, *c*). Over the head of the loom, and very often fixed to the ceiling of the weaving shed, is a board to which the main cords of the harness are fastened. The essential character of this board is fixity; no motion whatever is derived from it. Next below, and threaded on the cords, is another board, which is curiously perforated (fig. 296 *b*). In the board twelve rows of twelve holes are pierced, each hole terminating in a slit wide enough to let through a harness cord without rubbing it too roughly. Above this board the harness cords are knotted, the knots being designed to prevent the cords from passing through the slits; but the holes are wide enough to let the cords pass through easily. Connected by a lever with the crank shaft of the loom, the board has a vertical motion. Should any of the cords, therefore, be pressed by any agency into the slits, they will be lifted when the board lifts; those cords, on the contrary, which are in the holes, will pass through.

Still lower down on the apparatus, twelve sets of twelve needles are held horizontally by perforated needle boards. On one end of the needle springs are set, and facing the other end is a six-sided card cylinder. Through the eyes of the needles the harness cords are threaded. Some special features are to be observed in both the needles and lifting board in every kind of carpet; but the general structure may be considered first. A guide board leads the cords over the space intervening to the comber board. The latter is perforated with as many holes as the lifting board, but in a different order (fig. 296). They are ranged in diagonal rows of six holes each, a row of cords from the lifting board occupying two rows on the

SILK BROCADE (by Liberty & Co., Ltd.)

Machine-woven Reproduction of Old Chinese Embroidery made with four silk wefts on cotton ground

comber board. The cords are thus spread out, and have room in which to work. Above the bottom board the harness cords are knotted, and the latter may lift all the cords at once.

After passing through the bottom board, the cords are set with

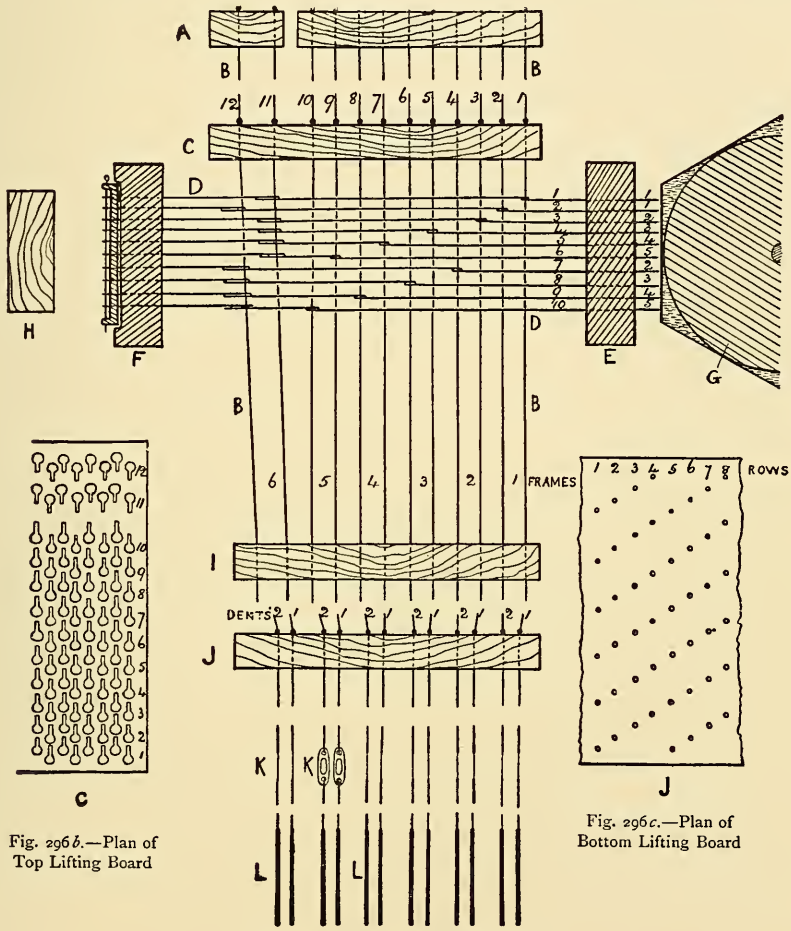


Fig. 296 *b*.—Plan of Top Lifting Board

Fig. 296 *c*.—Plan of Bottom Lifting Board

Fig. 296 *a*. Diagram of Brussels Jacquard

A, Stationary top-board. B, Harness cords. C, Top-lifting board. D, Needles supported in frames E F. G, Six-sided cylinder. H, Striking-up or levelling board. I, Guide board. J, Bottom-lifting board. K, Mails. L, Lingoes.

mails, into which the pile warp threads are run, according to design. On the ends of the cords lingoes are hung, to keep them steady and hold down the warp.

If we were working a figured plush with this Jacquard, the number of holes, cords, and needles would be greater, and the structure would be as described; but for a Brussels carpet of, say, six frames, some

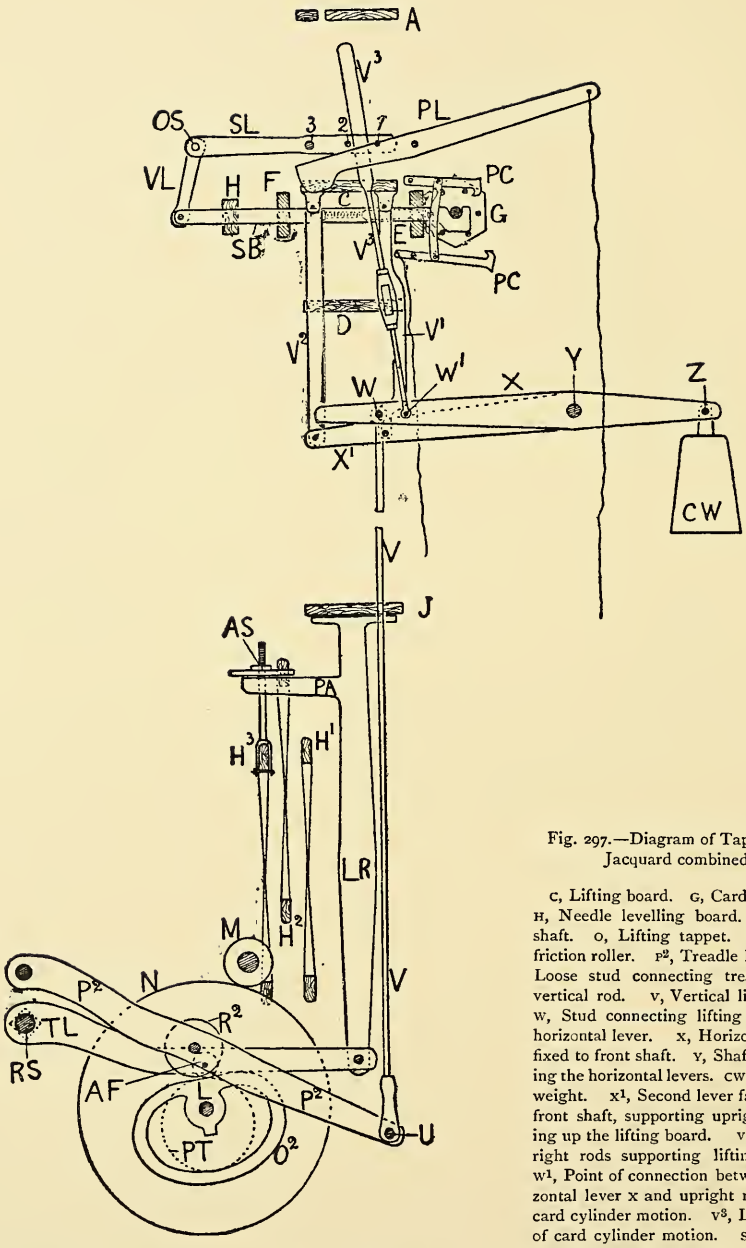


Fig. 297.—Diagram of Tappet and Jacquard combined

C, Lifting board. G, Card cylinder. H, Needle levelling board. L, Low shaft. O, Lifting tappet. R^2, Anti-friction roller. P^2, Treadle lever. U, Loose stud connecting treadle with vertical rod. V, Vertical lifting rod. W, Stud connecting lifting rod with horizontal lever. X, Horizontal lever fixed to front shaft. Y, Shaft supporting the horizontal levers. CW, Counterweight. X^1, Second lever fastened to front shaft, supporting uprights holding up the lifting board. V^1, V^2, Upright rods supporting lifting board. W^1, Point of connection between horizontal lever X and upright rod of the card cylinder motion. V^3, Lifting rod of card cylinder motion. SL, Simple lever passing through slot of V^3. 1, 2, 3, Studs on simple lever acting on upright rod V^3. OS, Oscillating shaft. VL, Vertical lever connecting oscillating shaft and the sliding bar of the cylinder motion. SB, Sliding bar. PL, Lever for reversing motion of the card cylinder, with string attached. PC, Catches which turn the card cylinder. J, Lower comber board. H^3, Heald shaft of stuffer warp. PA, Projecting arm holding the stuffer warp heald. LR, Lifting rod of comber board and stuffer warp heald. AS, Adjustable screw. PT, Plain tappet of the comber-board lifting motion. TL, Treadle lever of the latter. RS, Rocking shaft of plain tappet treadle lever.

difference would be made in the form of the lifting board and the needles employed. Every needle would have two eyes, and while the ten needles would each take a pair of threads from the five frames, the threads of the sixth frame would pass through five needles each in a given order. Complementary to this, a certain arrangement of the holes in the lifting board is necessary. The slits of the two rows of twelve holes are made opposite to the slits on the holes of the other ten rows. The normal positions of the two sets of cords are reverse. When no motion is given to the needles by the card cylinder, the cords of the sixth frame lift, while all the others remain stationary. On the contrary, whenever the cylinder acts upon a needle, it forces the cords of that needle into the narrow neck and the cord of the sixth frame upon that needle out of the slit, causing the cords of the other frame to lift, while the threads of the sixth frame remain depressed. This ingenious device enables the weaver to obtain the same results with ten needles, or ten sets of needles, which he would require otherwise twelve sets of needles to accomplish.

Ground-warp Tappet Healds.—The ground warp of plushes is shed by a tappet motion. The tappet most favoured is the Woodcroft, which, being positive, requires no other appliances for depression of the warp and spares complexity. Plates for this tappet are made in the ordinary way, the number of picks in the round being determined by the design.

Combination of Tappets and Jacquard.—Not in plush looms only, but upon many others, the heald shafts are combined with the Jacquard. In order that the two mechanisms may co-operate evenly, they are combined, the mechanism of the Jacquard being actuated by treadles from the tappets. It may seem a reversion to employ tappets and treadles for the Jacquard; but practical men care little for the symmetrical theories of progress. The instance is valuble as showing the essential function of Jacquard hooks and lifting griffe.

Looking closely at the machine (fig. 297), we find that the vertical shaft, upon which the whole movement of the Jacquard depends, receives its impulse from a treadle working by an antifriction roller in a tappet keyed on to the low shaft of the loom. Operated by the vertical shaft is a horizontal lever, weighted at the exterior end and firmly gripping on to a shaft which crosses from one side of the Jacquard to the other. Upon this latter shaft a set of levers supporting the lifting board are fastened, the horizontal ones supporting

each a pair of vertical levers, to the heads of which the lifting board is attached. This explains how the lifting board is elevated. By the revolution of the tappet the treadle imparts motion to the vertical shaft, and, through the various levers and shafts, to the lifting board.

The motion of the card cylinder has yet to be obtained. An ingenious combination of levers, moved by the same shaft and tappet treadle, accomplishes the purpose. On the horizontal lever directly coupled to the shaft connected with the treadle is a shorter vertical shaft, slotted to allow a short lever to pass through it at the head. A pair of studs limits the oscillation of the vertical shaft on this lever. At the farther end of the lever is a shaft from which another lever descends and connects with a horizontal bar. One end of the bar carries the card cylinder, while the other supports the back needle board.

The rotary motion of the cylinder comes from a contrivance similar to those on the ordinary Jacquards. At each end of a small bar, over the neck of the card cylinder, a catch is attached, projecting, the one above and the other below, over the card cylinder. A stud on the sliding bar of the cylinder touches either the upper or under half of the lever, and causes either of the catches to drop, pulling the cylinder round the sixth of a revolution as it passes.

We have seen that the whole of the pile warp of a plush fabric must be lifted clear of the ground pick, and to allow the wire shed to be made. The lift is accomplished by the bottom or comber board. A plain tappet is keyed on to the tappet shaft, and from the treadle working upon it a lever connects vertically with the comber board. It seems an objection that this is only a negative tappet, while all the others are positive; but the lingoes on the ends of the cords, and the gravitation of the other parts, are sufficient to restore the balance.

Working the Plush or Carpet Jacquard.—When the loom is at rest, and at what we may call the starting point, the tappets have the treadle bowls on their lower sides, and the card cylinder is in contact with the needles. Now the drive is on, and the loom begins to move. The tappets elevate the treadles, and the treadles move the vertical shaft, which lifts the horizontal lever; this, in the first instance, acts upon the oscillating shaft, controlling the supporting levers of the lifting board. All those cords which have been left in position by the now retreating card cylinder are elevated by the lift.

We have to examine, however, the work of this card cylinder and its effect upon the cords of the lifting board. Normally the knots of the cords are in the holes of the lifting board; when pressed by the solid card, the needles draw the cords into the narrow slits, so that they may be lifted by the board; those needles which have passed through holes in the card leave the cords untouched, with an exception of some importance. As pointed out formerly, the needles have two eyes, and the lifting board has two divisions of holes, the smaller division being the inverse of the larger. The slits of the holes in the board are turned in the same direction as the holes of the other division. Therefore the normal position of the cords is in the slits, and the action of the needles sends them out into the holes, as required. Again, the division of the yarn passing through the second eyes of the needles is always operated in the same way.

Suppose, for example, needles 5 and 8 are not acted upon by the card, then the warp carried in the second eyes of these needles will be lifted, because no action has taken place, and the cords remain in the narrow slits of the board. But if all the others have been driven out by the solid card, as may happen, none of them will act with their second eyes; the cords have been carried into the slits of the lifting board, and they are lifted, carrying the warp yarns with them.

Actuated by the same lever, the card cylinder has been sent out to the extreme of its course, there receiving one-sixth of a revolution from the projecting pawl; with the downward turn of the tappet, treadle, and shaft, the cylinder comes back, presenting the face of a new card, and impinges upon the ends of the needles, causing a new combination of cords to be lifted by the board, which immediately follows on its next lift.

Tying Up the Harness.—We have seen it stated in some dictionaries that there are as many hooks in a Jacquard as there are threads in the warp. This does happen, but the rule is quite contrary; there are only as many hooks as there are warp threads wrought differently into the pattern. Even this is not wholly or necessarily correct, but it describes the method of working most common; we shall examine the most conspicuous exception by and by. Conversely, we may have more hooks in the Jacquard than warp threads differently wrought in the pattern. A Jacquard with 100 hooks may be employed to work a pattern of only ten threads. It may be said that ten heald shafts would serve the last weave better; but circumstances alter cases, and practical matters admit of no abstract rule.

Two factors determine the tying up of a Jacquard harness, viz. the number of threads in the pattern, and the number of warp threads. A Jacquard hook and its attached cord are simply heald shafts in function. The same rule as governs the method of healding

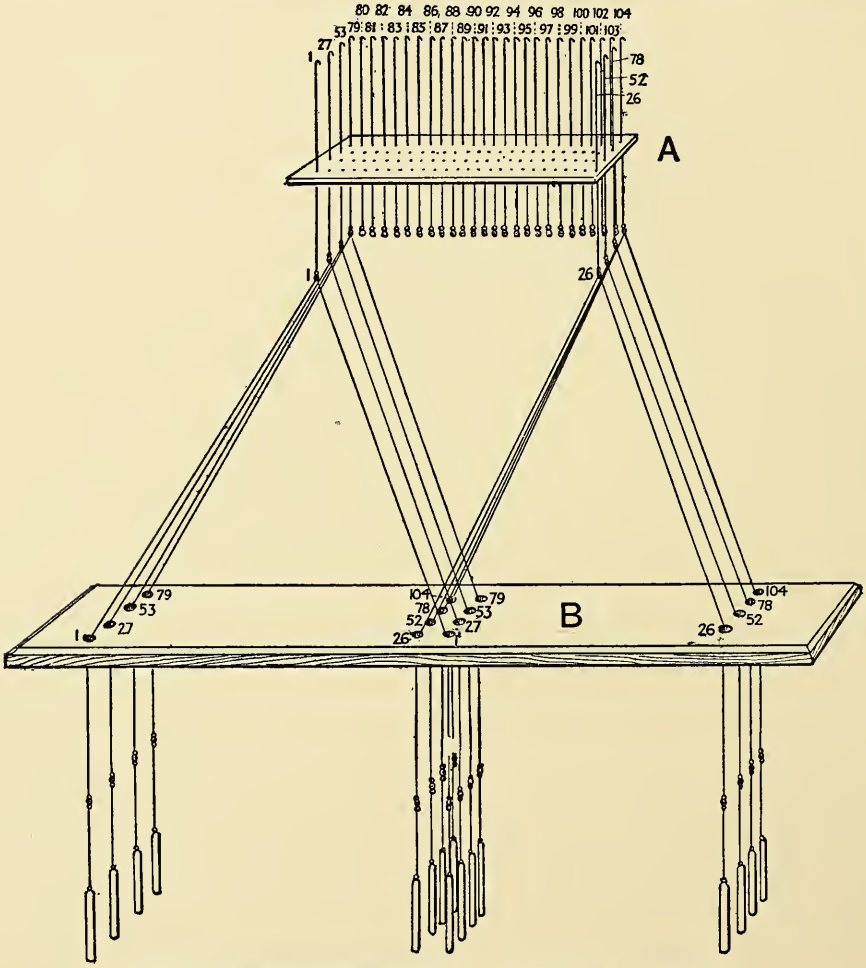


Fig. 298.—Harness of the Jacquard Loom. A, Neck board. B, Comber board.

must be observed in the tying up of the harness. All the warp threads which act throughout the web in the same way are to be tied up to the one neck cord, if there are as many changes of pattern as hooks. Alternatively, when the hooks are a multiple of the pattern, the adjacent warp threads are to be tied up together, and all those sets of warp ends acting the same way are joined to hooks which are to be lifted together.

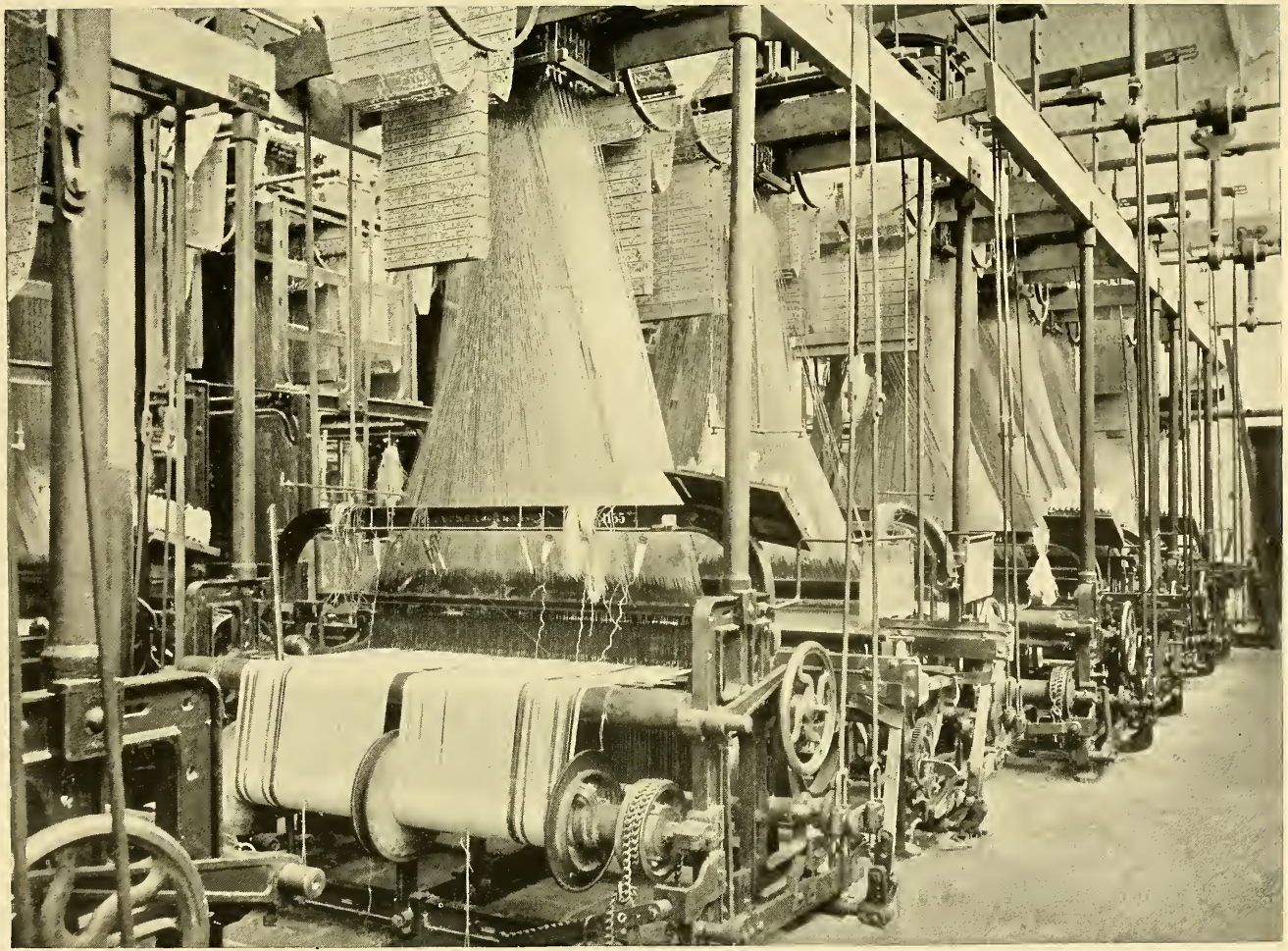


Photo. by Welch, Belfast.

PRESSURE JACQUARD WEAVING DAMASK AT MESSRS. W. EWART & SON'S MILL

Building up a harness is a long process; but it is a purely practical operation, needing little explanation. The neck cords are made of the proper length, and to these are attached as many harness cords as there are repeats of the pattern in the cloth (fig. 298). The comber board holds the cords freely over the warp, so that each one drops straight down. Without such a lever the harness cords would pull the warp threads in all directions, the very last thing to be allowed. With their lingoes on their ends, the mailed cords drop straight down, ready for the drawing in of the warp. Various methods of tying up and knotting the cords are adopted, the form of the Jacquard, the kind of cloth woven, and the position of the Jacquard on the loom all being factors to be considered.

Pressure Harness.—The linen weaver has been most exacting upon the capacity of the Jacquard. Some of the figured damasks would require in the ordinary way over 2000 hooks on the Jacquard; but a method has been adopted by which the number required has been reduced to a fourth or even a fifth of that number. This is called *pressure harness* (see Plate). A very good account of pressure harness appeared in an old number of *The Textile Educator*, published in 1889. "We will suppose", says the writer, "that it is desired to produce a pattern the extent of which will occupy 2000 ends. Instead of using a machine containing 2000 hooks, we may use a machine which will contain, say, one-fifth of that number—400. Then, as we attach only one harness cord to each hook, it will be necessary, to enable us to put in the full number of threads, to pass five threads through the mail or eye of the harness. Then to all intents and purposes these five threads become as one, so far as the harness is concerned, and although we have the 2000 threads, the limit of our pattern would be 400; but now we proceed to subdivide the five threads. In front of the harness we place five healds, and through each one is passed one of the five threads, which are passed through the mails of the harness. We have then the work divided into two distinct portions, viz. figuring and twilling, the first being performed by the harness, the twilling by the healds. It may now appear at first sight as though the figure would have a very coarse appearance from the fact that five threads must be raised and depressed at once by the harness; and so it might, if the picks were arranged in fives—that is, if each card served for five picks. But each card may serve for one pick only, and thus form the pattern as clear and perfect as if each thread had a separate harness cord, because no matter how

much or little of the harness may be raised to form the figure, the healds have precisely the same effect in forming the pattern on the ground. The eyes or mails of the pressure healds are made considerably longer than those of the ordinary healds, so as to allow of the proper formation of the shed. Of course the number of healds may vary according to the twill or satin of the ground. Thus, for a five-thread satin five pressure healds would be used, and five threads through each mail of the harness; for an eight-thread satin eight healds would be used, and eight threads through each mail of the harness, and so on. From this it will be seen that whatever number of threads are passed through the mail eye of the harness, they must all be actuated at once, and the picks may be either single or one card may serve for several, which will be kept from passing into precisely the same shed by the twilling healds." Referring to the exact ratio of threads in marls to shafts, Professor Fox says: "This is by no means the case. The number of shafts in use does not control the number of threads in a mail, neither does it control the number of picks to a card. Thus with eight shafts there may be from two to eight threads in a mail, and the card may equal two to eight picks, but it does not follow that each mail will contain the same number of threads, and that each card will equal the same number of picks in any fabric."

A certain degree of technicality enters into the foregoing, and the writer is open to criticism in several particulars, but the general meaning is clear. The object is to give a weft face to the ground and a warp face to the figure. A great strain is put upon the warp, and many attempts have been made to obviate the trouble in various ways; but none of the twilling machines produces an equally firm texture. We may combine the heald motions with the Jacquard, work the healds by tappets, or employ dobbies for that part of the operation.

Jacquard Problems.—On the old forms of Jacquard, in which the hooks were ranged only in rows of either eight or twelve, the harness builder had considerable trouble in finding in the pattern a common multiple of the hooks in the machine. Alternatively, he often failed to find in the number of hooks on the Jacquard a multiple of the threads in his pattern. With a greater variety of sizes of Jacquards this difficulty does not so frequently occur, but the problem of distributing the pattern upon the hooks yet remains. It is not often we find a pattern which contains such a number of threads as will

multiply into the number of hooks on the Jacquard; at least to limit designs by that consideration would hardly answer our needs.

Suppose a 400-hook Jacquard tied up so that as the cords pass through the comber board they give 100 to the inch; then the space occupied by one division will be 4 in. We have a pattern occupying 380 ends to work; this means that 20 hooks in the machine must be "cast out"—left aside. But some plan of casting out is required. A guide to the only practicable plan is offered by the fact that 380 threads must cover the whole 4 in. occupied by the 400 threads or hooks. This gives 95 to the inch, or one hook in 20 left out.

Besides telling us the rate of casting out, the foregoing argument shows the number of threads to the inch a 400-hook Jacquard will work of the given pattern. We can get no more than 95 threads to the inch. The rule is: As the number of hooks in the full harness is to the number employed, so is the number of threads to the inch which would be carried by a full harness to the number of threads to the inch in the hooks employed.

Very often the designer proposes an opposite problem to the weaver. He has designed a cloth the pattern of which occupies 380 warp threads, and desires that not more than 95 threads should be put into the inch. A 400-hook Jacquard is the nearest to that required, and it gives 100 to the inch. We have these factors: 100 hooks to the inch as compared with 95; 400 hooks in the whole machine to 380 in the pattern. Equating these, we find that 20 hooks have to be cast out. The rule may be stated thus: As the number per inch in the harness is to the number per inch required, so is the total number of hooks in the machine to the number which must be employed. For obvious reasons the simplest example has been selected; the problems presented in practice are much more difficult; but the rules are unfailing.

Other factors, however, enter into the practical problems which have not been stated. So many threads are given to make the lists; these have to be taken into account when measuring the size of the Jacquard. Another problem occurs in the tying up of the harness. The question comes as to how many harness cords will be given to each neck cord. First find the hooks in the Jacquard available for the pattern, then multiply the number of ends per inch by the breadth of the warp, and divide by the number of wires available.

CHAPTER VII

The Reed or Sley

The Reed.—On the power looms of the present day the reed and its connections take an active part in the manipulation of the warp. Formerly the functions of the reed or sley were confined to the preserving the order of the warp threads and beating up the weft into the warp after the shuttle had passed. These still remain the most important functions of the reed, but some others, with proper appliances, have been added on.

Up till early in the eighteenth century the reed was composed of split canes. John Kay, the inventor of the fly shuttle, conceived the idea of making the teeth of metal, and carried it out, with a very effective result. Excepting among silk weavers, who always seem reluctant to take up improvements, the metal reed was soon accepted by the whole weaving industry.

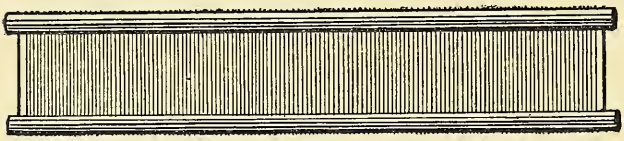


Fig. 299.—Reed or Sley

Structure of Reed.—The teeth of the reed are thin, narrow ribbons of metal, bound edge outwards within pairs of thin wooden laths at their ends, the binding being usually of tarred twine. When finished, a reed appears to be two round wooden laths holding between them, along the whole length, a series of flat wires facing each other.

A reed maker would call the ribbons of metal dents or teeth; but we speak of the spaces between the wires as dents. Reeds are fine or coarse according to the number of dents contained within an inch. Coarse reeds, used for thick cottons and heavy woollens, have 6 dents to the inch. Silk reeds are the finest, and range as high as 125 to the inch. For special purposes the dents of the reeds are very wide apart; but for common work the limit is 1 dent to 1 in.

Counts of Reeds.—Like the counts of yarns, the counts of reeds have been fixed by local custom in various localities, with an equally confusing result, many of the districts having different units multiplied in various ways. At Huddersfield and Radcliffe, and in the United States, the unit is 1 in., and the reed is named according to the number of dents contained in 1 in. In the woollen districts of Scotland, the unit is the whole length of the reed most commonly used, viz. 37 in.,

and the denomination of the reed is based on the number of dents contained in that length. The Stockport unit is 2 in., while that of Macclesfield is 36 in. Another series of systems has for basis the number of times 200 dents will go into a certain number of inches. Bolton reed is named according to the number of times 20 dents go into a length of 24½ in.; Bradford length unit is 36 in.; Dundee (jute), 37 in.; Yorkshire worsted, 54 in. Dewsbury has for a dent unit 19, in a length unit of 10 in.; the dent unit of Holmfirth is 5, and the length unit 12 in. Silk reeds are most explicitly named; the term of description includes all the factors. When naming a reed, the weaver or reed maker gives the number of teeth in the reed, the number of threads it is intended to take through in one dent, and the total length of the reed; as, for example, a 2000 reed, 8 threads, 24 in.

With such a diversity, a common measure is rather diffiult to lay down. It is greatly to be desired that reed makers would set up a common standard. In all weaving we have the formula: So many threads to the inch. Why not base the reed measurement on the same unit? Professor Fox has compiled a neat little table showing what would be the dents per inch of all the different counts, if reduced to a common measure.

Locality	No. of Reed	Dents per inch
Radcliffe	1	1
Huddersfield	,, ...	1
American	,, ...	1
Stockport	,, ...	0.5
Scotch	,, ...	0.02702
Macclesfield	,, ...	0.02778
Bolton	,, ...	0.8247
Bradford	,, ...	0.5556
Dundee	,, ...	0.5403
Worsted	,, ...	0.3704
Dewsbury	,, ...	0.2112
Holmfirth	,, ...	0.4167

Reeding or Sleying.—A theory of reeding or sleying has yet to be founded. Up till the present no satisfactory basis has been discovered. We can only give a few practical hints on the subject. The old rule was to assign one split or dent in the reed to every pair of warp threads. In those days, when four, six or eight threads were passed through one dent, it was denominated *cram*, and the practice was resorted to for distinct purposes, such as the production of repp cloths, in which the

warp threads were shed in sections of so many threads, to give the ribbed surface. Modern practice, however, has advanced beyond that. We weave a common twill with a reed having four threads in the dent, and find it of some advantage. Several variable factors enter into sleying problems: thickness of yarn, number of threads to the inch, and the character of the pattern, as well as the style of forming the cloth, which may be different in every factory. For example, some woollen manufacturers believe in weaving a sound cloth on the loom; others weave it in open style, relying upon the milling to bring it together, and that in various degrees. Roughly speaking, the number of warp threads to the inch determines the count of the reed, given that we have already determined how many threads are to go into each dent. In sleying, the weaver has to consider how many threads to the inch will produce a good cloth of a given pattern. Close sleying gives a fine, firm cloth, wide sleying produces an open texture.

Place of the Reed in the Loom Structure.—Before going farther with our examination of the reed, it is necessary to show what place it occupies in the power loom. As the reed is part of the going part, or batten, we shall risk repetition and describe the whole of that section of the loom. A rocking shaft extends across the loom, near the base, hung in bearings bolted to the side frames; upon each end of the shaft a slay sword is firmly pinned, the two forming the supports of the batten, which of course forms a bar across the web on the loom. The sole of the batten, called the *slay sole*, is a stout bar of wood, bolted to the swords, and of breadth enough to carry the shuttle race and the reed. To the shuttle race, which is a smooth piece of wood laid over the front of the batten sole, we need not attend at present. A groove of the breadth and depth required to hold the lower rib of the reed is made in the upper face of the sole, behind the shuttle race. The reed is carefully fitted into the groove. Another piece of wood, grooved upon its under side, and bolted to the heads of the swords, forms a cover for the head of the reed, and is called the *sley cap*. Thus fixed, the teeth of the reed stand up vertically at right angles from the warp, offering a clear passage to the threads, while regulating and dividing them.

Loose Reeds.—Beating up the weft into the warp is the secondary function of the reed. It frequently happens that the shuttle, from some cause or another, stops in its course across the loom; the coming reed beats upon the shuttle and smashes it through the warp. If the

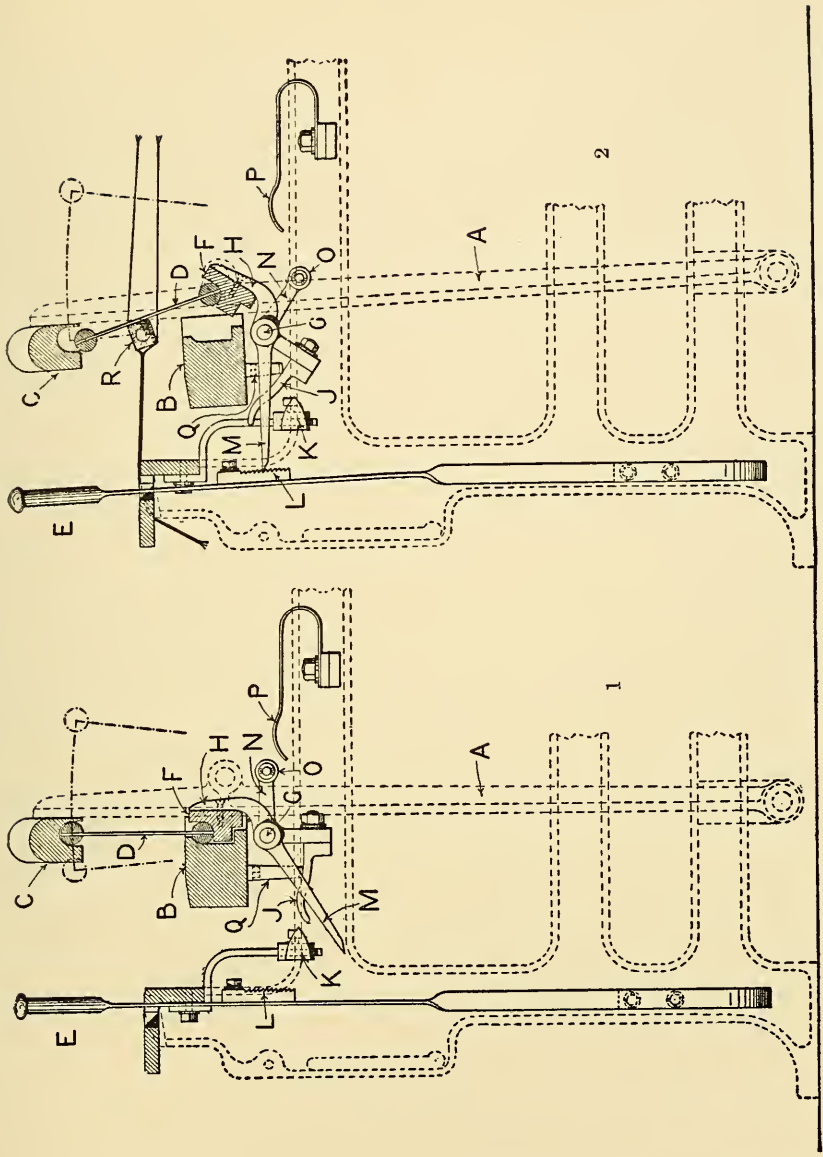


Fig. 300.—Loose-reed Stop Motion. A, Sword. B, Shuttle race. C, Reed cap. D, Reed. E, Starting handle. F, Loose strip extending along the shuttle race behind the reed. G, Rocking shaft of stop motion. H, Arm on rocking shaft holding the loose strip in place. J, Curved arm projecting towards the front of the loom from the rocking shaft. K, Frog fixed to breast beam of loom. L, Corrugated buffer on starting handle. M, Dagger on rock shaft, projecting forward to strike the buffer on the stop handle when the shuttle is trapped and the reed loosened. N, Lever on rocking shaft projecting backward to a flat spring and supporting the holders of the loose strip. O, Roller on end of lever N. P, Flat spring. Q, Spring fixed on base of slay sole, and pressing down J. R, Shuttle trapped in warp.

reed is rigid, as it must be in the structure just detailed, smashing is almost certain to occur at some time or other in heavy looms driven at high speed; but weavers have not been content to allow such a disaster to be placed in the category of unavoidable accidents. From a very early period in the history of the power loom, attempts have been made to obviate the risk of disaster should the shuttle stop in the warp. To detail all the devices in use, not to mention the numerous contrivances

which have been invented, would take longer than the importance of the subject warrants. We think one or two of those most in use will answer our purpose.

Spring and Lever Loose Reed.—In this arrangement the back of the batten sole is cut away from behind the reed, and a separate piece, facing an iron support set upon an oscillating rod extending the full width of the slay, is placed to the back of the lower rib of the reed. Attached to this lever is a light spring, the other end of which is linked into a hook in the sides of the swords. Continuing the lever is a finger projecting in front, and coming into contact with a cone-shaped frog held by a bracket in the front frame of the loom. So long as there is no pressure on the reed, the finger is kept low and passes under the cone, being held firmly to the back of the reed at the moment of beating up. If, however, the shuttle stops in the warp and the reed is pressed back, the spring gives way, and the finger is lifted; this brings it on the upper side of the rigid cone, which causes it to tilt back and release the reed.

This contrivance has been improved and extended in various ways. It was found that, if the springs were made strong enough to keep the reed in position, they failed to give way in time to save a tender warp from damage; if too light, the reed was apt to break away at the very moment of beating up. The finger lever was extended back, and a bowl put on the end of it, to run easily along a flat spring curving to the framing where it was bolted. Aided by this the spring could be made very light and yet serve the main purpose.

Another addition was a long rod projecting from the mechanism, which, when the reed was thrown loose, was lifted up into contact with a handle acting on the driving-belt fork. The rod struck the projecting buffer on the handle shaft and caused the loom to stop. One of the best examples of this motion is shown in fig. 300, 1 and 2.

Still more efficient are those reed-relieving motions which act in conjunction with the shuttles. While the shuttle is crossing, the reed is almost free, and not until it has entered the mouth of the opposite shuttle box does the mechanism holding the reed firmly in place come into action. Shuttle-box swells, however, belong to another part of our subject.

Criticism has not yet said its last word on the subject of loose reeds. Objection is taken on the one hand to the best of these contrivances that the reed is never secure, and that for heavy looms the danger from loose reeds failing to beat up is as great as the danger from stopped

shuttles. On the other hand, it is objected to the newer and better forms that the shuttle has already enough work to do, without putting upon it the burden of the loose-reed appliance. Upon these points we need hardly pause to give an opinion, the whole question being a matter of practical expediency. With proper care the loose reed appliances now at the command of the weaver should work satisfactorily. Certainly the danger of smashing shuttles is worth some trouble to avoid.

Some Special Forms of Reed.—For the production of waved warp weaves and gauzes special forms of reed are made. Unwilling to allow any part of his machine to pass without contributing something to the realization of his artistic desires, the weaver has made the reed serve him in several ways. The ordinary plain reed (fig. 301) is a series of straight wires.

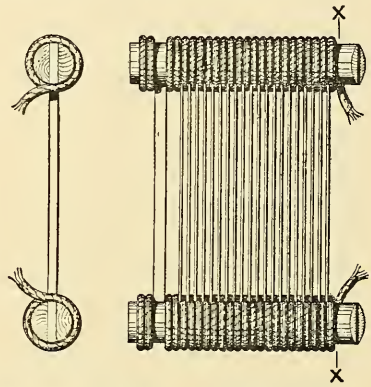


Fig. 301.—Ordinary Plain Reed

Waved Warps.—The reed teeth in this weave are set in angular fashion, one set widening at the base and converging at the head of the reed, and the other side widening to the head and converging at the base. In itself that arrangement of the teeth would produce little or no effect; but the reed is geared to a pair of cams which alternately raise and lower the whole reed regularly, or at such intervals as the design requires. The converging dents bring the warp threads close together, and the widening dents open them out (fig. 302).

Gauze Reeds.—The crossing threads of gauze require a certain area of freedom which the common reed does not afford. In those sections of the reed carrying the crossing threads the teeth are not extended from rib to rib, but are curved in the form of a series of arches, so that the threads may run from the one dent into the other without hindrance (fig. 302). Another (fig. 303) has a half dent, through the eye of which the crossing thread passes, the reed acting like a heald.

Terry-towelling and Drawn-warp Motions.—Some ingenious weaver conceived the idea of utilizing the reed for the purpose of making drawn-thread cloths, tucks, and flounces on the loom, and the idea was further extended in the effort to produce pile cloth without wires. The latter, though applied to terry towelling and such coarse fabrics, has

never been successfully employed in the making of true plushes or pile carpets.

Hacking's Terry Appliance.—The fascination which the idea of causing the warp to loop and draw automatically has exercised upon loom mechanics is very extraordinary. Few ideas have been the subject of so many patents. One reason for the phenomenon is given by

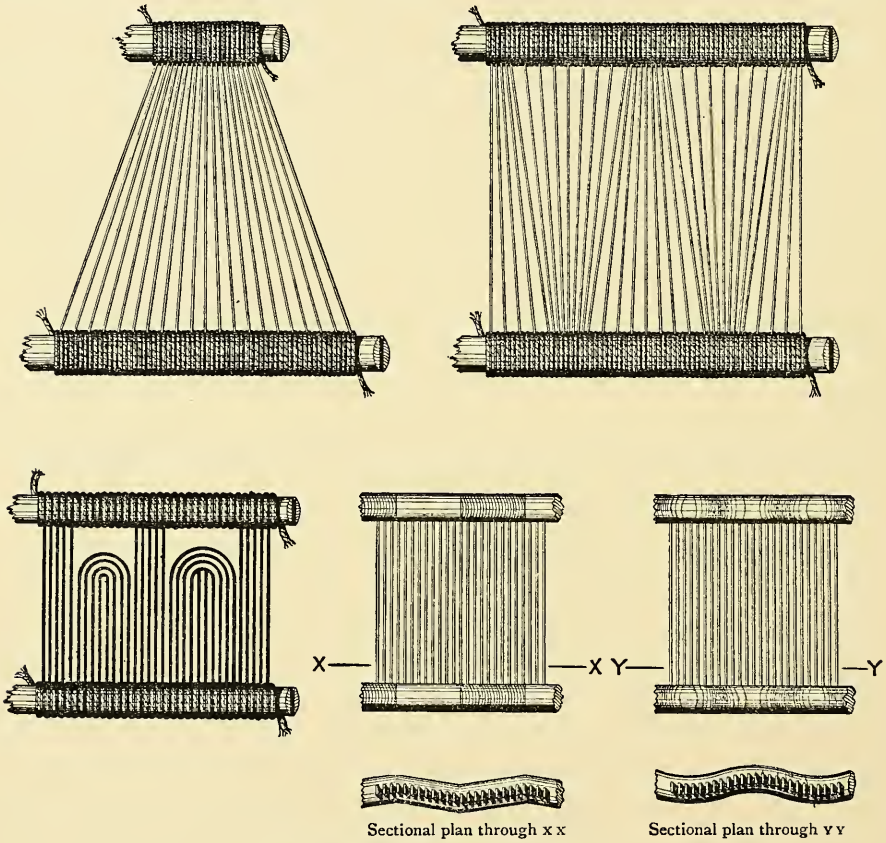


Fig. 302.—Various Forms of Special Reeds

the remark of a well-known manufacturer, that all profit has vanished from common cloth weaving, and the only road to fortune is the invention of some fancy cloth of which you can hold the monopoly for a season. From the many we select one which illustrates clearly enough the principle of the motion.

The basis of the Hacking terry motion is a loose reed which swings freely in the slay cap (fig. 305). The bottom rib of the reed is enclosed in a case united to the heads of the slay swords by a lever. On the

head of the lever a bowl is pinned which rolls along the top of the horizontal arm of a double lever fixed to the ear of the swords, until stopped by a regulating pin or stud placed in its line of traverse. Parallel with the lever controlling the reed case, the second arm of the double lever is joined to the former in two places, the one in the middle by a slotted lever restricted by a stud, and the other by a spring near the basis of both. At the end of the double lever is a stud into which a hook coming from a cranked lever, connected at its other end with a dobby or Jacquard mechanism by a wire, is linked. When, by the lift of the Jacquard hook, the hook of the cranked lever pulls the stud end of the lever, the coiled spring draws the lever holding the reed case, causing the reed to be loose, and to precisely the length which the bowl on its head is permitted to roll along the lever adjacent. The pile warp is drawn forward, therefore, every pick, but is not beaten up. Then the Jacquard drops the cranked lever, and the hook becomes disengaged from the end of the double-armed lever; the spring then acts in the opposite direction, making all the parts lock together and fixing the reed case rigidly. The beating up then takes place.

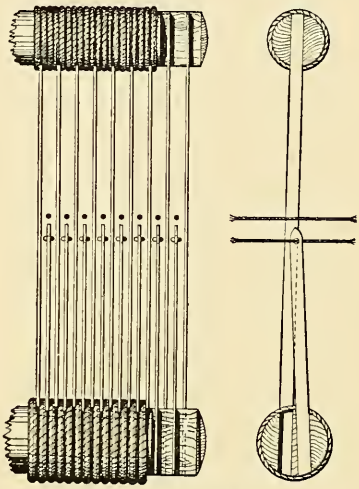


Fig. 303.—Gauze Reed

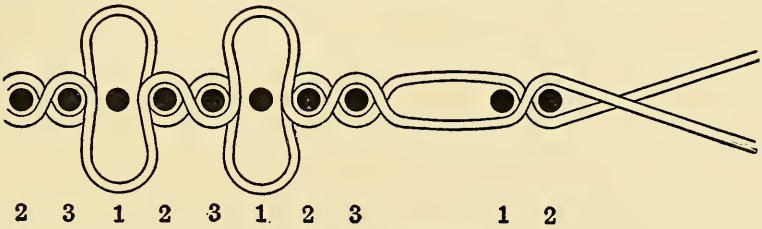


Fig. 304.—Section of Terry Towelling

Pick 1 is at first not beaten up. Pick 2 is driven against pick 1. Pick 3 is then beaten up, driving all three threads home and raising the loops

Ground warp and pile warp are on separate beams, the former being held as tensely as the strength of the yarn will admit, and the latter weighted lightly, so that it comes away easily. The natural effect is a series of loops on the pile warp, one loop to every pick, which, when the number of loops designed have been made, are beaten up by the

locked reed. A heavy plain cloth can, of course, be woven between the sets of loops.

Crinkled or Drawn-thread Cloths.—Contrivances similar in principle to the terry-towelling appliance are employed in making fancy crinkled cloths. The main difference to be noted is that the relative proportions of the warp threads are reversed, and that the drawn warp is tense while the ground warp is slack. A simple method of accomplishing the purpose is the nipping of the drawing warp behind the reed by a pair of intermittently driven rollers. Held firmly while the mass of the warp goes forward, the drawn threads compel the ground warp and woven cloth to crinkle up, in order to maintain an equality between them. Very frequently variation in warp tensions is produced by difference in rate of letting-off.

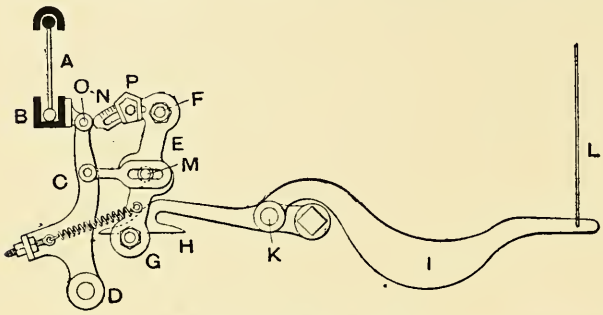


Fig. 305.—Hacking's Terry Motion

A, Reed. B, Case for bottom of reed. C, One of the arms supporting case. D, Rod connecting arms carried on swords. E, Double lever. F, Fulcrum of double lever on ear of sword. G, Stud at base of vertical arm of double lever. H, Hook which catches in stud. I, Arm or lever of hook. K, Joint of hook and arm. L, Lifting wire. M, Stud in slotted fulcrum of vertical arm of the double lever. N, End of curved arm of double lever. O, Bowl running on curve. P, Stud stopping the traverse of bowl.

Lappets on the Power Loom.—It is not easy to exhaust all the ingenious methods by which the weaver has made the reed serve his ideas. In many a weaving shed cloths are produced which puzzle the expert cloth designer, and reeds play frequently an important part in the mystery; but that aspect of the subject belongs almost wholly to the practice of the highest experts. We can only indicate that it exists.

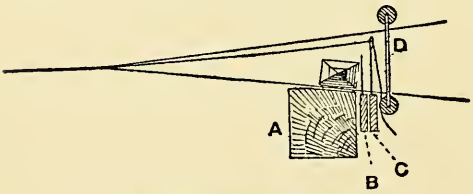


Fig. 306.—Lappet Weaving

A, Stay sole. B, Pin rail. C, Needle rail. D, Reed.

Closely associated with the reed is that form of fancy figuring, mostly applied to gauze fabrics, known as *lappet shedding*. For many years this style of weaving was regarded as a monopoly of the hand-loom weaver, and a considerable proportion of lappets are still wrought on the hand loom. As explained in the section on the hand loom, the

apparatus consists of needle bars set in a groove between the shuttle race and the reed, whip rolls or bobbin stands carrying the extra warp for the figures; and a lappet wheel, for the guidance of the needle bars in forming the figure (fig. 306).

The mechanism of this loom may be viewed in three parts, viz. the motions of the lappet wheel, the pin and needle bars, and the whip rolls (fig. 307).

Grooves are cut in the lappet wheel to guide the peck or finger

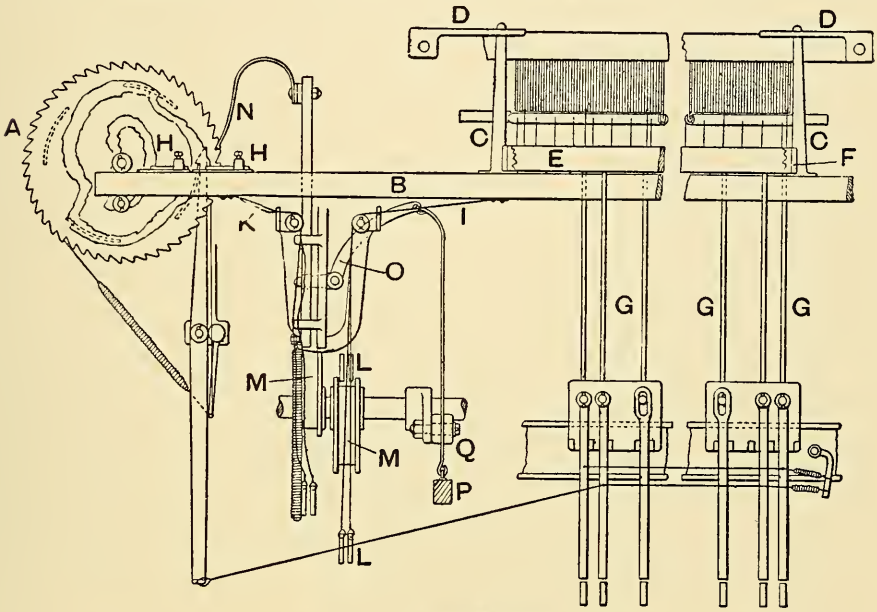


Fig. 307.—Lappet Mechanism

A, Lappet wheel. B, Shifter frames. C, Vertical guiding slides. D, Slotted plates for slides. E, Pin bar. F, Needle bar. G, Vertical levers on rocking shaft lifting and depressing the bars. H H, Pecks or fingers of shifter frames. I, Strap from treadle lever. K, Strap connecting shifter frames with short ends of bent levers driven by cams. L L, Bent levers. M, Cams. N, Spring controlling lappet wheel. O, Cranked lever acting on shifters through the straps. P, Treadle of shifter frame tappet. Q, Tappet on low shaft.

of the shifter frame which imparts lateral movement to the needles or needle bars. Mounted upon a stud bolted in a slotted rail attached to the loom swords, the lappet wheel receives motion from the low shaft of the loom. From the short arm fixed on the low shaft the force of the revolving shaft is sent through a series of springs and levers, mutually acting, on to the toothed edge of the lappet wheel, moving it round a tooth for every two picks of the loom.

The second part is more complex; it is a species of tappet shedding, revealing the essential character of the lappet whip as extra warp. The reed proper is fitted so as to leave a space of 3 in. between it and the

race board; the cap is bolted on the back of the two swords, and the bottom rib is set in the semicircular metal trough bolted farther down on the same side of the swords. Within the space thus made the pin bars, needle bars, and shifters work. The pin bar looks like a kind of improvised reed, without the top rib. At each end of the bar a brass tip with grooves is fixed, and the bar is held in place upon the slay by the grooves fitting into slides on the inner sides of the shuttle boxes. Iron plates on the bottom of the bar protect it at the points where it is acted upon by the lifters, which raise it as the slay goes back and depress it as the slay comes forward to the cloth. Pins are set in the bar, at intervals of about 1 in.

Needle bars are wooden laths, fully longer than the width of the web, $1\frac{1}{2}$ in. deep, and about $\frac{1}{4}$ in. thick. Needles are stuck in the bars at distances regulated by the number of threads which are to be worked into the breadth of the pattern; standing about $2\frac{1}{2}$ in. out from the bars, the needles are flat, with eyes drilled near the heads. Lined on the under side with iron, and bound with brass on the ends, the bars are held by metal slides coming up from the shifter bars below, the slides being slotted in plates fixed over the reed cap. As will be shown, the bars have both a vertical and a horizontal motion, the latter, of course, being the more important.

Shifter bars impart lateral motion to the needle bars. Longer by a half than the needle bars, the shifters extend out to the side of the loom and insert a finger into the lappet-wheel grooves; the uprights which hold in slides the pin and needle bars are bolted to the shifters; while having no control over the vertical actions of the needles and pins, the shifters carry them with whatever lateral motions they make. Tappet cams upon the bottom loom shaft cause the shifters to act, through the media of two sets of levers or treadles, one to each tappet. Straps are bolted to the ends of the shifters, and pass over pulleys to the levers. As the tappets rotate, the levers rise and fall alternately, and as the straps on one side tighten, the shifters are drawn from right to left, and into contact with the lappet wheel; as the straps on the other side are tightened by the other levers, the shifters move from left to right, and away from the lappet wheel.

The vertical action of the bars, however, has not been explained. Upon the rocking shaft at each side a bracket is fixed, and upon these brackets studs are held by screws, each stud serving as the fulcrum of five levers from which rods extend vertically up to the ends of the needle and pin bars. That is to say, a pair of rods are assigned

to each bar. The ends of the rods are bent flat, so as to form a base for the bars. As the rocking shaft vibrates, the rods rise and fall, causing the needle and pin bars to lift and sink up to and below the level of the warp.

From the *whip rolls*, or, as it may be, bobbins, the whips, or extra warp, pass over a pair of tension wires bound by twisted cords to a pair of flat springs. Thus retained, the whip is given off according to the rise and fall of the needles through which they have been

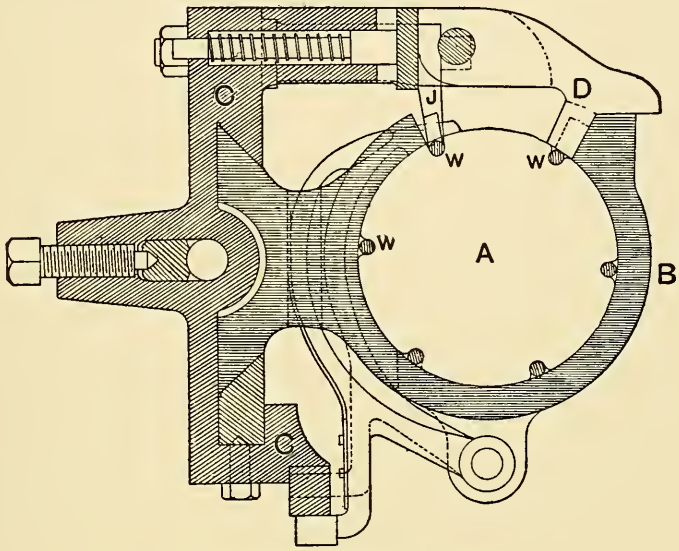


Fig. 308.—Wire-inserting Motion (section)

A, Roller. B, Casing. C, Slide carrying finger D and pawl J. W, Wires.

threaded. As we have indicated, the main parts of the whole apparatus are carried upon the swords and swing with the slay.

Variations on this lappet mechanism have been introduced, some for the purpose of adding to the mobility of the needles and the whip yarns they carry, and others to give a better guide to the pattern-forming finger on the shifter bars. One very strong objection to the lappet has always been the stiffness of the figures it makes, and there is some ground for the criticism. Many efforts have been made by inventors to redeem the lappet from this defect, and we think some success has been achieved. One very common pattern among the most recent is the distribution of small detached figures over the foundation cloth. This is made by causing the whole of the needle bars to drop out of gear through the action of a vertical

bar called the long catch, one end of which inserts a finger into the lappet-wheel grooves, while to the other end cords controlling the needle bars are attached. Strips of metal are placed in the face of the lappet wheel at the intervals required and of the length proportioned to the spaces between one spot and another; these render the needle bars inoperative till the long catch has passed the metals and the action is resumed. The various other additions and improvements consist of minor adjustments easily understood when seen in actual working.

Wires in Pile Warps.—All forms of plush fabrics, from the finest velvet to the heaviest Brussels carpet, are looped up by wires being woven into the pile warp. The hand-loom weavers who weave the velvet robes of princes and peers insert the wires by hand, laboriously laying each one under the pile warp and withdrawing the first of three or four inserted, to keep up the supply. Power-loom weavers, however, need automatic supply of wires, and the gradual evolution of the wire mechanism on the plush looms forms an interesting chapter in the history of weaving. Wires vary in thickness and length according to the width of the fabric and the depth of the pile; but the wire must at least be as long as the width of the cloth. To insert and withdraw such a length of wire on a loom, without occupying enormous space, was the problem. One

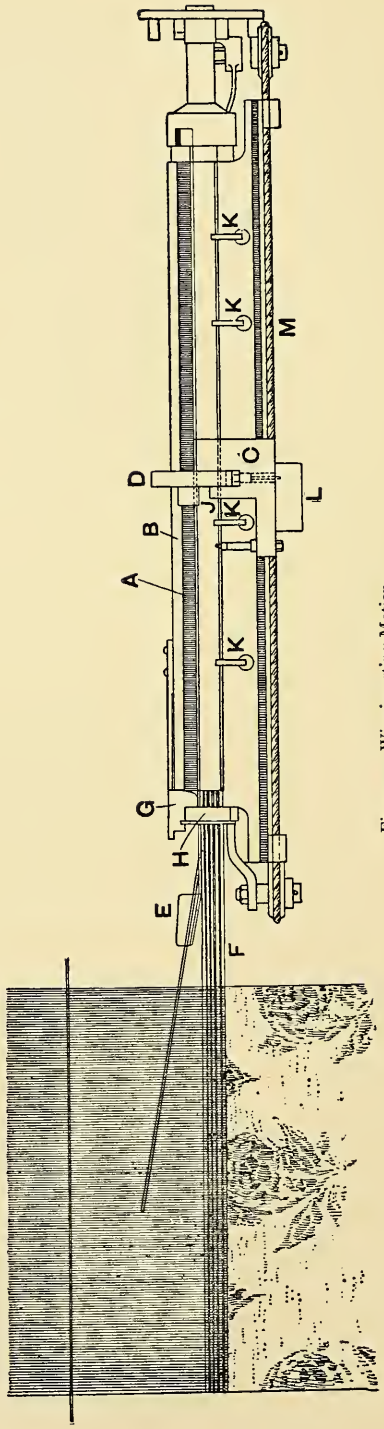


Fig. 309.—Wire-inserting Motion

DESCRIPTION OF FIGS. 309, 310

A, Roller in which six grooves are cut for the wires, and which turns $\frac{1}{6}$ of a revolution at a time. B, Casing. C, Slide carrying the finger D which pushes one of the wires out at each stroke. E, A guide which directs the wires into the space between the two warps. This guide drops out of the way as soon as the wire is placed in the shed, as shown by dots in fig. 310. F, The ends of the wires in the loops of the fabric, kept in position by the head of the spring G and the hoop H. When the roller is stationary one of the grooves is opposite the wire just inserted, and the next is opposite the wire to be withdrawn. When the slide C arrives at the inner end of its traverse, a pawl J attached to it is tripped up by the head of this wire, which it drops over, grips, and withdraws. K K are curved fingers whose office is to hold the wire in the groove of the roller during withdrawal. These fingers are lifted out of the way in turn by the double incline L on the bottom of the slide C. M is the driving rope attached by a block and set screws to the slide.

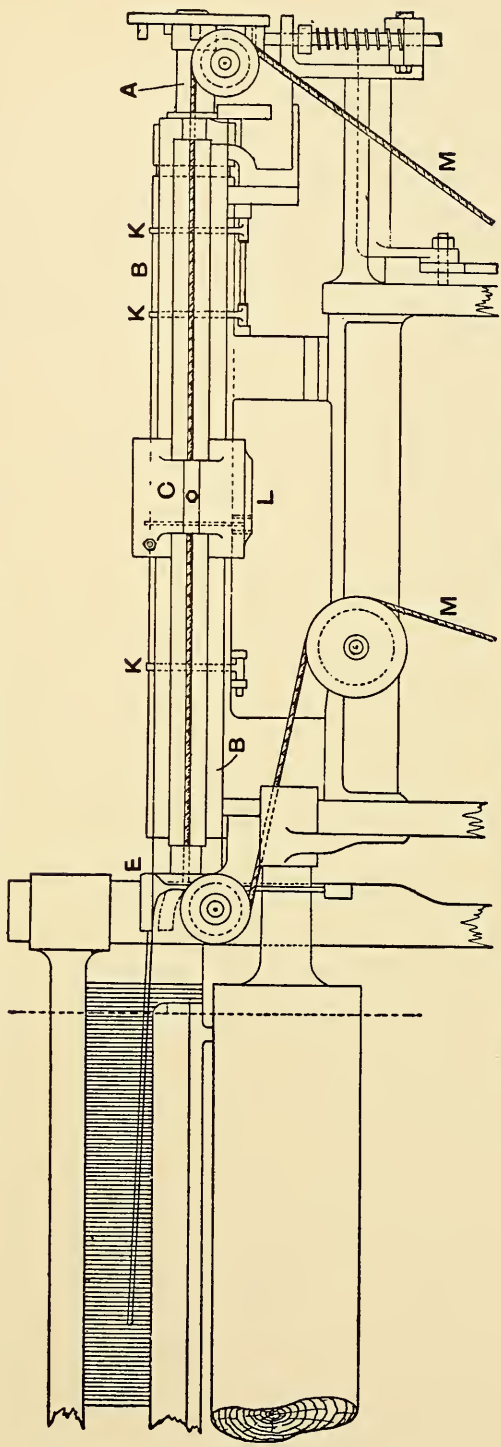


Fig. 310.—Wire-inserting Motion (from Spons' *Encyclopædia of Arts and Manufactures*)

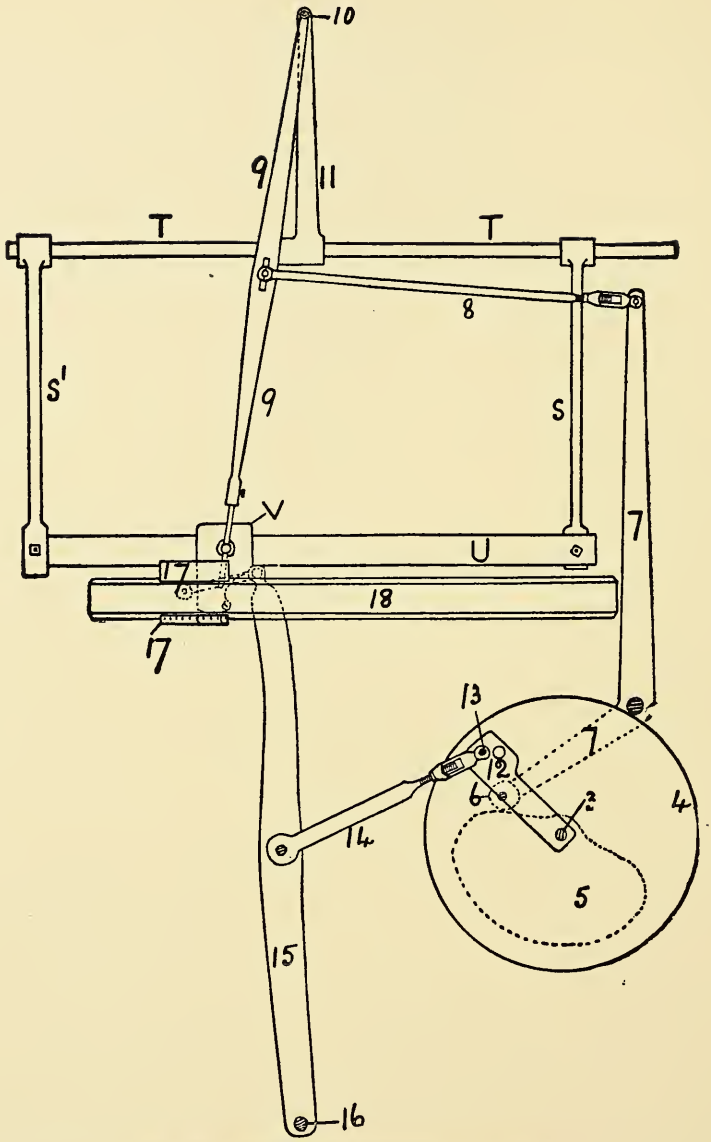


Fig. 311*a*.—Elevation of Wire Mechanism (cradle motion)

of the earliest automatic appliances illustrates this vividly. Upon a magazine at one side of the loom the wires were piled in order, each wire having a hook at each end. A reciprocating rod at one side drew the wire into the warp by linking a hook into the hook of the wire; a similar rod at the other side drew the used wires out of the cloth in the same way, delivering them loose, to be laid by the weaver

into the magazine again. The space occupied by such a loom was double that of any ordinary loom, and more. The operation, also was slow and troublesome.

Roller-wire Appliance.—The greatest step towards automatic wire

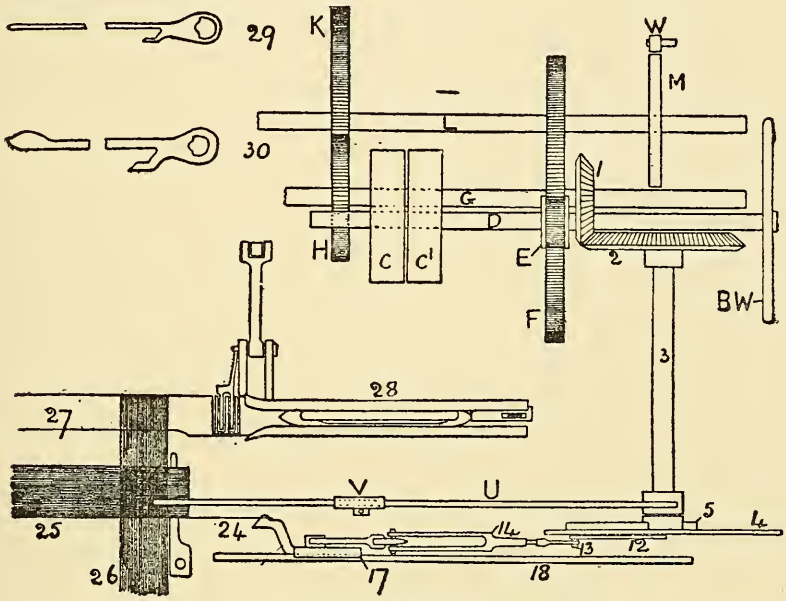


Fig. 311 *b*.—Plan of Wire Mechanism (cradle motion)

Description of Figs. 311*a* and *b*

M, Tappet securely fixed to shaft L and kept in rolling contact with anti-friction roller W, which by means of levers not shown oscillates the levers S and S^1 rigidly fixed to shaft T. These levers support the bar U, on which the hopper V can readily slide backwards and forwards. The shaft 3 carries a smooth disc 4; on the inner side of this disc a tappet 5 is kept in rolling contact with anti-friction bowl 6, which is free to revolve on the lower arm of lever 7. 8 is an adjustable rod connecting levers 7 and 9. The lever 9 is centred, and swings from stud 10 at the top of lever 11, which is secured to shaft T. The lower end of lever 9 is in the form of a spindle, which moves freely in a groove of a stud in hopper V, and is capable of moving V along the bar U. 12 is an arm or plate attached to disc 4, and is connected with the lever 15 by means of the arm 14. 17, Hook box, which is free to slide on the bar 18, and is supported by lever 15, centred at 16. The hook 24 serves for pulling the wire out of the fabric, and placing the head of the wire in the jaws of the hopper V. The warp threads are shown at 26, the race of the going part at 27, and the shuttle and shuttle-box at 28. 29 and 30 represent the separate wires for Brussels and Wilton carpets respectively. G is the crank shaft, and D a supplementary shaft driven through pulley C, and fitted with a balance wheel BW, which drives the wire mechanism through the shaft 3.

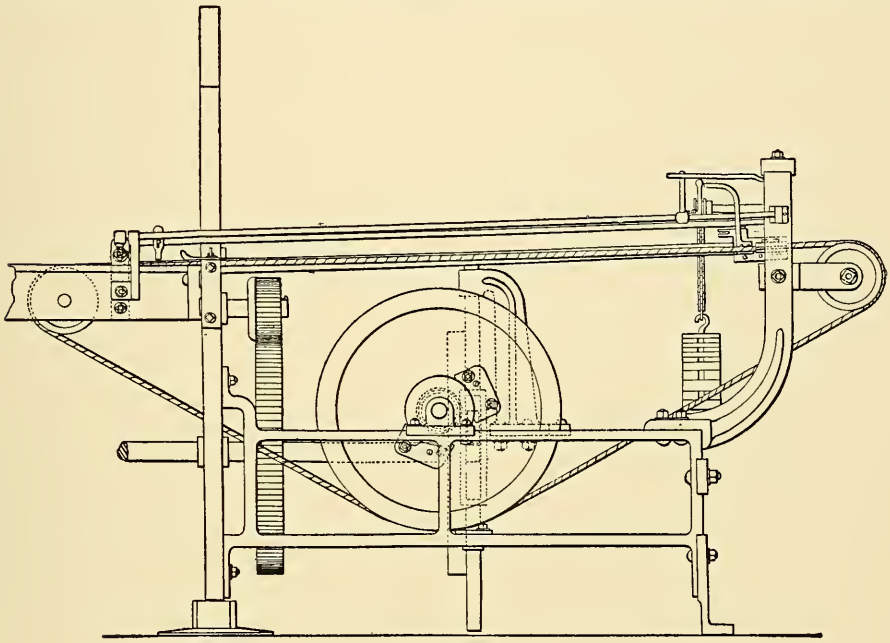
weaving was taken by the inventor of the roller-wire mechanism. His contrivance has been improved upon, but it is still in use (figs. 308, 309, 310). At one side of the loom a roller grooved in six sections, each section equal to the space occupied by the inserted wires in the cloth, is placed. Wires are placed in the grooves. On the roller casing a slide with two fingers is set, the one for pushing out and the other for withdrawing the wires. When the

wire is pushed out into the shed, its end falls into a hoop which steadies and brings it into position for lying in the warp. At the same moment the hooking finger acts. If the number of wires has already been inserted, it withdraws the one first put in, and the returning action of the slide sends it into the empty groove of the roller. There are always four wires in the fabric, one coming out and one going in. At every action and reaction of the slide the roller revolves one-sixth of its circumference, bringing an empty groove opposite the first of the set to be inserted, and a full groove into the range of the pushing-out finger and slide. If carefully set, and operated with due attention, the roller mechanism performs very well, though it is admittedly not ideal.

Cradle or High-wire Motion.—The most efficient and most complex of wire-weaving mechanisms is that known as the cradle or high-wire motion. Through a train of pinion wheels this appliance is driven direct from the main shaft of the loom drive, and every part is rigid, all the motions being accomplished by levers, rods, and tappets on the most exact mechanical principles. The hopper containing the wires is set upon a frame formed by a pair of vertical shafts free to oscillate upon a shaft lower down in the loom. This frame is called the *cradle*, and its variable motion comes from a tappet on the bottom shaft of the loom, through the medium of a set of levers. Actuated by a shaft driven from a bevel wheel working in the boss of the wheel rotated from the main shaft, a tappet causes the hopper to move to and from the edge of the cloth, along the top of the rod supporting it, the motions being conveyed through mutually acting levers. A carrier lever, peculiarly shaped, and having an independent motion of its own from the low shaft of the loom, supports the wire when it leaves the hopper till it enters and rests in the shed of the pile warp, and after it leaves the warp on its way back to the hopper. Next we find the hook which withdraws the used wires; it sits on the end of what is called the *hook box*, moved to and fro upon a fixed shaft by levers from the same disc as directs the tappet of the hopper. The action of these parts, together with the complex mass of levers and shafts and rods, is lucidly described by Fred Bradbury in his book, *Carpet Manufacture*, as follows:—

"The hopper commences to move the wire towards the fabric as the slay is travelling towards the harness, and by the time the reed has almost reached the cloth on its return journey the hopper has fully inserted the wire into the pile shed; during this period the

cradle has been moving with the hopper to suit the position required by the wire at the various points of its insertion. Immediately the wire is driven home, the hopper and cradle remain at rest, close against the wires for a period of about half a pick in Brussels, but for a much longer period in Wilton; this longer dwell is necessary for the purpose of keeping the wire upon its edge until the weft on the next pick



Front Elevation

Wire

Fig. 312*a*.—Hall's Improved Wire-inserting Motion

has been inserted and somewhat bound down the pile threads into the body of the cloth. After this the hook box comes along with its hook, and pulls out of the carpet the first-inserted wire. Meanwhile the hopper is holding the last wire in position in the fabric, after which it follows the hook box with increasing speed; this it not only overtakes but slightly passes—the jaw of the hopper and wire hook are close to each other at this particular period. The hopper is then reduced in speed so as to permit the hook box and hook with its wire to gain gradually upon it, and thereby to draw

the wire head into the jaw prepared to receive it; then hopper, hook box, and hook travel together for a time until the hopper reaches its extremity of traverse; but the hook continues to travel with its constant variation in order to be in position to draw out the next wire on the pick required. The return journey of the hopper occupies about seven-eighths of a pick, but the motion is invariably accelerated and retarded. Commencing its return journey slowly, at first, it increases in speed for about half its traverse, then it decreases in

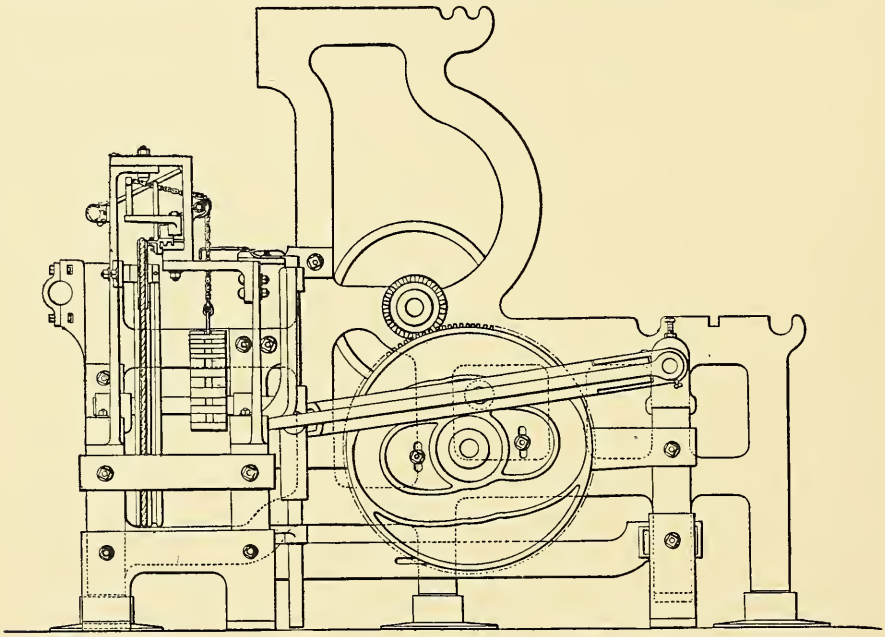


Fig. 312 *b*.—End Elevation of Hall's Wire-inserting Motion

speed for about a fourth of the journey, and afterwards slowly, but variably, travels with the hook box nearly to its termination. The hopper travels somewhat farther than the hook box, so as to allow the wire head to get clear of the hook. There is practically no dwell allowed for the hopper at the end of the slide remote from the cloth."

Some of the other plush-pile appliances are lighter and less complex than the high-wire apparatus, and rather more suitable for the lighter fabrics. A favourite is the "Moxon" type, of which Hall's improved wire-inserting motion (figs. 312 *a*, 312 *b*, 312 *c*) is a good example. On this mechanism the wires are carried in a trough placed at the side of the loom, level with the warp, and above the rope and pulley driving

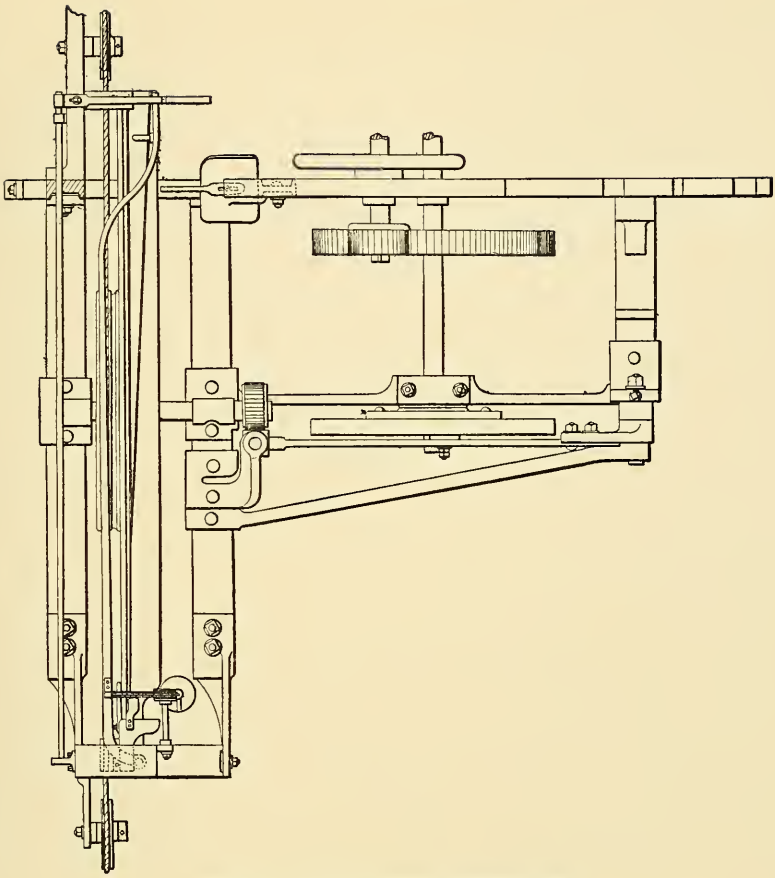


Fig. 312 *c*.—Plan of Hall's Wire-inserting Motion

gear. The rope has a windlass motion on the large wheel, which is driven by a tappet and gearing behind, controlled by the shedding motions of the loom. From the diagrams, the movements of the driving and wire-inserting mechanisms can be easily followed.

CHAPTER VIII

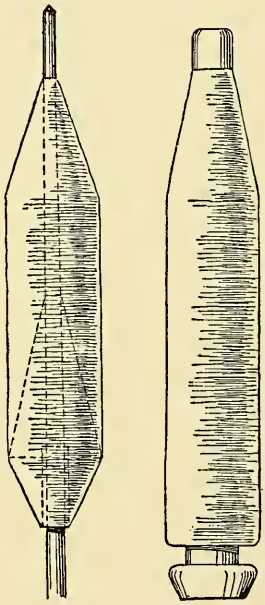
The Weft Mechanism

Weft.—The correlative of warp is weft; together they make up the fabric. In all his manipulations of warp the weaver is making equal play with weft. To flush a warp end is to hide a pick of weft; to flush a pick of weft is to sink an end of warp. Closely

associated at every moment on the loom, warp and weft are yet independent; the weft is contained in a shuttle moving freely and unattached, driven by appliances unconnected with the mountings which control the warp. The prime defect of the power loom, as a mechanical invention, is the impossibility of controlling the weft and warp by the same mechanism. Against this disability inventors and loom-builders have striven in vain. Begun as an imitation of the hand loom, the power loom cannot be divested of the essential principle of its original. Wefting or picking is the craft of the hand-loom weaver; he retains it literally in his own hands. On the power loom, insertion of the weft becomes only one of several operations which ought to be co-ordinated as closely as possible. A contradiction so essential would seem to point to the need of inventing a power loom different in conception from the hand loom. During the past hundred years ingenious mechanics in both hemispheres have laboured unceasingly to produce such a weaving machine, but the problem has not yet been solved. In this case necessity has not brought forth invention.

Fig. 313.—Spool

We have been promised great developments in the near future, and the omens certainly seem propitious; but our business is with the power loom now working. As it stands at present, the weft mechanism of the power loom is independent and separate from the machinery of the warp, and consists of weft spool, shuttle, shuttle race, shuttle boxes, pickers, and picking appliances.



Mule Cop Weft Cop

Fig. 314

The dotted lines show the stages in which it is built up

Spools of Weft.—Up till about the middle of the nineteenth century the slender, tapered wooden tube, called a *pirn*, was the universal weft spool. Cotton weavers began the change by accepting direct from the mule spinner cops wound on a stiff paper core; later, the cores were discarded, and the solid cops of yarn taken straight off the mule spindles. Solid cops are now greatly favoured in all classes

of weaving, though the pirn is still used throughout the trade; in some places pirns are used exclusively, and there are few weaving sheds where they are not to be seen in one form or another.

Flanged at the base and hollow at the core, the common pirn screws on to the tongue of the shuttle. Weft cops require a tongue the full length of the cop, hinged into the inside of the shuttle. If the

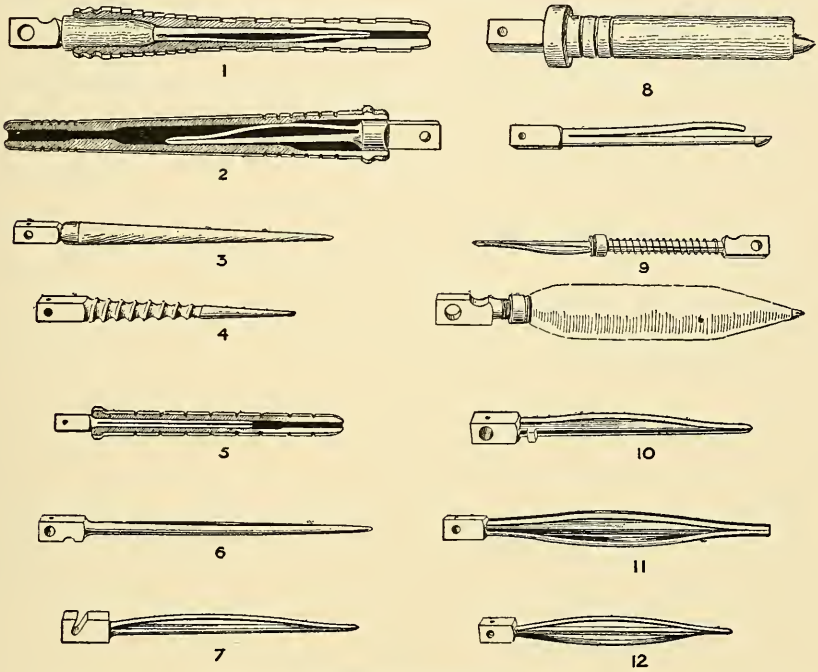


Fig. 315.—Shuttle Pegs (Wilson Bros. Bobbin Co., Ltd.)

1, Spring peg with wood collar for bobbin. 2, Safety peg for ring twist bobbin. 3, Turned wood peg for cops spun on taper tubes. 4, Malleable-iron screw peg for cops spun on taper tubes. 5, Tweezer peg for pirn. 6, American peg (both sides alike). 7, Peg with slotted head for easy changing. 8, Neb peg for worsted spools. 9, Peg with spiral spring for lessening drag. 10, Safety peg for pirn with internal groove. 11, 12, Pegs with extra springs for wide paper tubes.

cop is to be unwound from the centre, the inside of the shuttle then becomes a kind of weft case, with letting-off appliances. Much ingenuity has been spent in devising shuttle pegs (fig. 315), every variation in the form of spool and cop being provided for.

Shuttles.—The common shuttle is boat-shaped, tapering at both ends to a blunt point, tipped with steel cones. Made of hard wood, a cone-shaped hollow is made in the middle of the shuttle, the base being at the butt end and the apex at the point. Near the apex, at the side, a hole, termed the *eye*, permits the thread from the spool to come outside the shuttle. To prevent the thread from wearing

into the wood, shuttle eyes are lined with bone, porcelain, or some other hard substance (see Plate).

Shuttles are of many sizes; as a rule, the finer the weft the smaller the shuttle, though the trade customs and other varying conditions also dictate the size of the weft carrier. When we remember that the shuttle is driven across the loom, through the warp shed, the size of the shuttle appears to be a matter of some importance. The smaller the shuttle the lighter the strain upon the warp and the less power needed to drive it. No satisfactory standard or rule has been found. Choice of a shuttle depends upon conditions hardly to be estimated outside the weaving shed.

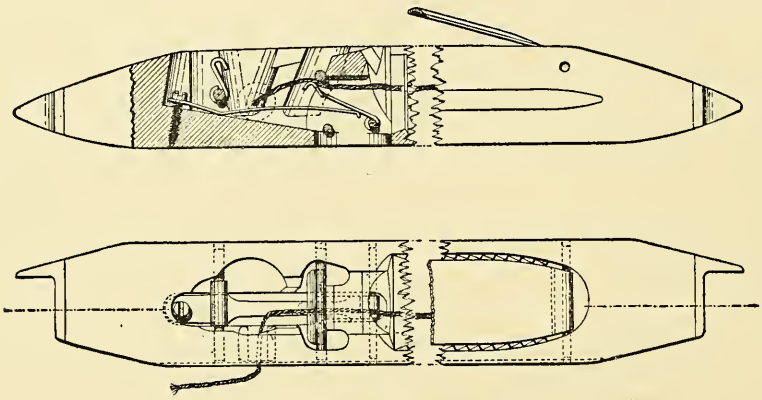
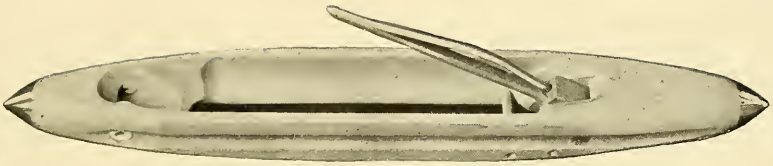


Fig. 316.—Ireland's Drag Shuttle

In choosing a shuttle the weaver must keep in mind the principle of balance. The weight should, as nearly as possible, be kept in the centre of the shuttle. With a full shuttle it is easy to bring the weight to the centre; but when the cop has been almost spent, the balance is changed, and the nose may tend to lift, a smash being almost certain to occur. For these reasons the weight of the shuttle, when carrying a full cop, should bear towards the nose. Another point to be considered is the relative weights of shuttle and weft. To make the drive easy, some weavers resort to light shuttles; but if the cop is heavy when full, the decrease in weight by the spending of the cop will be relatively great; a stroke which drives a full shuttle correctly will be too strong for an empty one. To ease the drive of heavy shuttles, little rollers are set in the wood at both ends, just level with the surface. If the rollers are of metal, they give weight to shuttles otherwise light.

Plain shuttles work best, but weavers of carpets, jute, linen, and

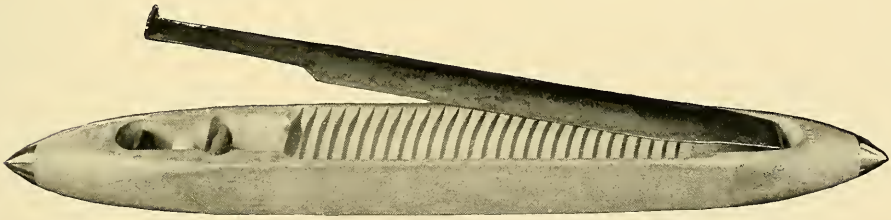


No. 1.

No. 2.

No. 3.

No. 4.



No. 5.

SHUTTLES

(By Wilson Bros. Bobbin Co., Ltd., Garston, Liverpool)

No. 1. Shuttle with wire pin to engage the shoulder on the pirn. No. 2. Shuttle with space for pad to serve as a drag on the weft. No. 3. Shuttle with special under-clip for pirn. No. 4. Section of No. 3. No. 5. Grooved shuttle for weaving canvas, sacking, &c.

various fabrics have sought to make the internal structure of the weft carrier serve other purposes. Patent shuttles have been chiefly designed to regulate the unwinding of the weft. These are generally employed on cops unwound from the centre, and may be described as boxes, with springs at the eye, which act as drags on the thread (fig. 316). Between a small plate and the weft pin, the weft is let through, a spring behind the plate keeping regulating tension on the passing thread.

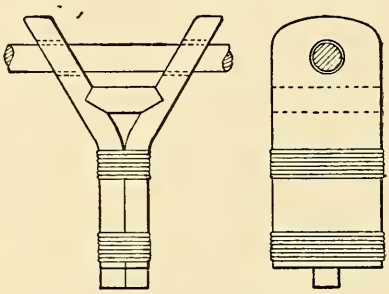


Fig. 317.—Y-shaped Picker

Special forms of shuttle and weft carriers are required in automatic looms. These, however, are examined at length in the chapter devoted to the leading models of the automatic weaving machines.

Shuttle Boxes.—Before we can understand the second of the main motions of the loom, viz. picking, a general notion of the structures and appliances operated upon must be obtained. On the power loom shuttle boxes have been developed into highly complex forms, with mechanisms corresponding, which must be studied in detail and for themselves. The plain shuttle box, however, will sufficiently show the sphere of the picker's action and the principles of the picking motions.

Plain shuttle boxes are practically continuations of the batten sole, boxed in on three sides, the mouths of the boxes facing each other across the length of the batten. Made higher than the height of the largest shuttle likely to be employed in the loom, the sides are thin but strong, while the end is a solid block of wood, holding a strong spindle, the head of which is clasped in a clip forming a bridge over the mouth of the box. Along this spindle the picker runs, driving the shuttle before it.

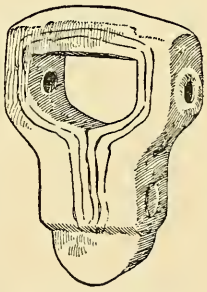


Fig. 318.—Hide Picker for Power Loom

Pickers.—Made of various materials, the pickers in common use are Y-shaped, the body being threaded on the spindle and the arms attached to the picking arm by straps (fig. 317). Drawn by the action of the picking arm, the picker strikes sharply on the butt end of the shuttle and drives it from the box across the loom, through the open warp shed. The material most commonly made into pickers is strong buffalo-hide leather, pressed and oiled (fig. 318). Many belt

manufacturers make a speciality of pickers, the offal and scraps from the heavy belts being utilized, to the advantage of both belt manufacturers and weavers, the former obtaining a profit from a material otherwise waste, and the latter getting pickers both strong and cheap.

Picking Motions. — There are three different picking motions operated on the power loom. These are: 1, *the cone pick*; 2, *the over pick*; 3, *the under pick*. We have noticed the difficulty which the separation of the picking and shedding presents, and the principle needs to be generally accepted. On the other hand, however, the mechanisms in actual working may be closely linked together; the shuttle is free and requires appliances of its own, but these appliances may be linked on to the rest of the loom.

Cone Motion.—During the past forty years the cone motion has been on more looms than all the other motions put together. Several factors contribute to the popularity of the motion; but the broad explanation is that it is workable under average conditions by persons of average intelligence. The parts of the cone picking appliance are few and simple. It consists of a picking arm, with strap attached to the picker, a picking shaft upon which a projecting cone is fixed, and a tappet on the low shaft of the loom.

The picking shaft may be placed either inside or outside the loom frame; in the latter case the picking arm must be made longer than in the former. A footstep holds the base of the shaft, forming a socket in which it may turn freely but steadily. Round the neck of the shaft a collar, with spiral spring attached to the side of the loom frame, is placed, the spring being set to bring the shaft round to its normal position after whatever pressure is put upon it has been taken away. The cone is firmly bolted into the lower end of the shaft, in contact with the tappet.

Before we can consider the shape of cone and tappet and their relations, we must know something more about the other part of the structure. Upon the head of the picking shaft we find the picking arm, and the length of this arm is of significance. Suppose we choose to work the shaft inside the loom, then the length of the arm must be a little less than half the width of the web. For a web 45 in. wide, we require a picking arm 21 in. long. On the top of the picking shaft a toothed ring is fixed; a corresponding ring is placed firmly within the socket of the block holding the arm; the two are fitted into each other, and the picking arm held rigidly on the head of the shaft.

According to our construction, the cone and the picking arm are parallel arms of the lever which is the picking shaft. Therefore, two problems, the converse of each other, occur. By the motion of the shorter arm the longer arm is driven. We require to find, on the one side, the distance through which the end of the long arm will move, the length of the short arm and the distance of its traverse being known; and, on the other hand, the distance the short arm must move to give a certain traverse to the point of an arm the length of which is known. The space separating the point of contact with the picking cone and the cone fulcrum is, according to Professor Fox, the point to be dealt with; but as that varies with the movement of the upright shaft, we take the length of the cone as the factor.

Rule to Find the Traverse of Picking Arm.—Multiply the length of the picking arm by the distance traversed by the short arm, or cone, and divide by the length of the cone.

Example: The picking arm is 21 in. long; the length of the cone 4 in.; the traverse of the cone is 6 in. Therefore: $21 \times 4 \div 6 = 14 =$ the traverse of the picking arm.

Rule to Find the Traverse of the Cone.—Multiply the length of the picking arm by the length of the cone, and divide by the required traverse of the picking arm.

Example: The length of the picking arm is 21 in.; the size of the cone is 4 in.; the traverse required is 14 in. Then: $21 \times 4 \div 14 = 6 =$ the traverse of the cone.

Structure of Cone Picking Tappets.—Picking appliances are on both sides of the loom; the stroke of each tappet is, in consequence, alternate. The crank shaft of the loom must, therefore, revolve twice for every single revolution of the tappet shaft, the two tappets being pointed in opposite directions, so that when the one is down the other is up. In structure the best form of tappet is composed of three parts or pieces: The *socket*, fitted closely to the shaft; the *disc*, held in the socket; the *nose*, or tappet proper, bolted to the disc.

Upon the relation which the form of the nose bears to the cone the efficiency of the tappet and the regularity of the picking stroke depend. If both were straight, and placed in the same horizontal line, the stroke would be sudden, sharp, and jerky; but though such an action would send the shuttle flying through the loom, it would be both ineffective and destructive. Look, for a moment, at the picking arm. A flexible strap connects the picker with the picking arm,

and when at rest it is slack; if not tightened a moment before the driving stroke, part of that force is expended upon the strap, straining and injuring it. Even with the very best adjustment of tappets, cones, and picking arms, a good deal of force is uselessly expended, and we must see to it that no more is lost. For these reasons, both cone and tappet are shaped in such a manner that the former will receive

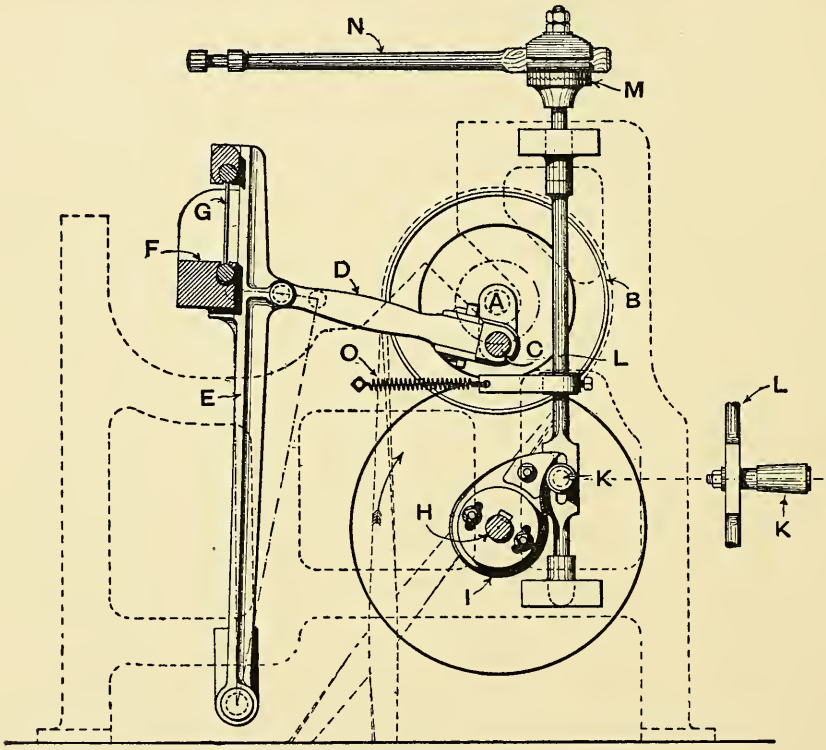


Fig. 319.—Cone Picking Motion: Beginning of the Stroke

A, Crank shaft. B, Driving pulley. C, Crank. D, Connecting arm. L, Picking shaft. M, Clutch. N, Picking arm. O, Spring to return N to

the early part of the stroke of the latter in a gradual rate of acceleration, terminating in a decisive stroke (fig. 319).

When the tappet first comes round, it meets with the widest part of the cone; the motion imparted also is to be graded; therefore the tappet should be hollowed so as to lessen the force of impingement while keeping close contact with the whole surface of the cone. Following the taper of the retreating cone, the tappet must also bring gradually greater force upon it; in order to effect that purpose the curve of the tappet must incline towards the cone (fig. 320).

The tappet has a blunt point which impinges directly upon the side of the cone, driving it sharply.

Shaping the tappet will thus be seen to be a matter of some difficulty. In practice, many weavers adopt a simple method. They cut out a rough shape of the tappet in cardboard and set it in the position of the tappet, working it on the cone and marking the shape

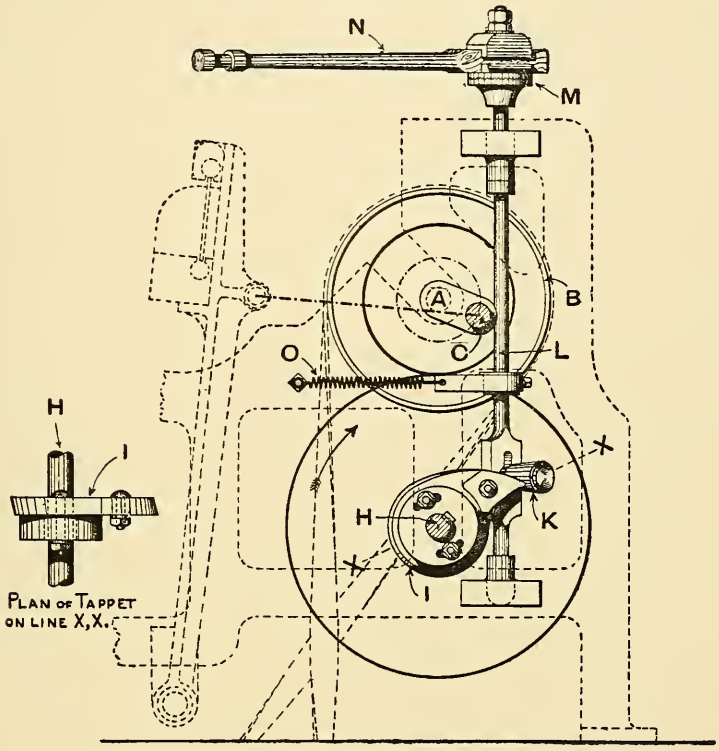


Fig. 320.—Cone Picking Motion: End of the Stroke

E, Sword. F, Shuttle race. G, Reed. H, Low shaft. I, Tappet. K, Cone. normal position after stroke.

which appears best for picking. A more scientific method, however, and one likely to bring the best results and save time, is similar to that detailed in the making of warp-shedding tappets. It has been objected that the taper of the cone presents an obstacle to that method, and makes it too elaborate, if followed to the utmost limit. The main outlines, however, can be obtained, and then allowance made for the taper of the cone.

Another and less complex method is to take the point on the tappet where the cone comes into contact with it, and divide the rest

of the length of the tappet into equal parts, five or seven as may seem best (figs. 321, 322). From each line of the divisions draw a diagonal line, successively shortening the angle between each pair of lines. The longer the curve the larger the share of the revolution of the tappet that part will take; the shorter the curve or space, the shorter the time occupied.

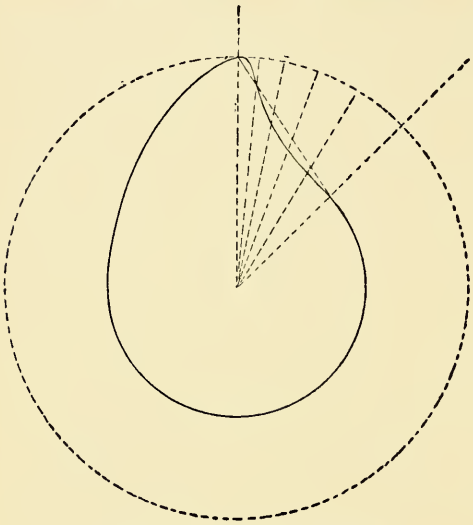
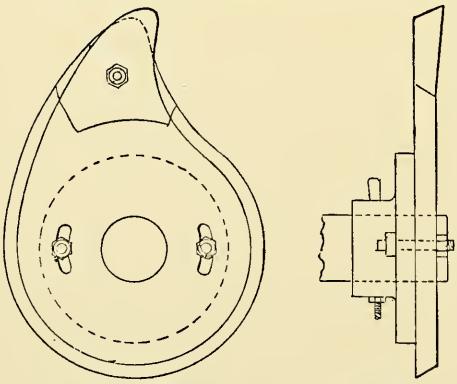


Fig. 321.—Construction of Cone Tappet

Upon the whole, practical men define their methods rather obscurely; they have not formulated a complete theory, and the varying conditions found upon different looms render abstract rules almost futile. The tappet may have been constructed upon the very strictest mathematical calculations, and yet may fail to supply the place of one made by a worker proceeding upon intuition and mere experience.

Action of Picking Shaft and Arm.—When the slay is retreating from the cloth fell, the tappet comes into touch with the cone, and tightens the picking strap; when the slay has reached the centre of its backward swing, the shuttle has begun to move, driven by the sharp stroke of the tappet, now brought full force on the cone; the picking shaft has been turned round in the short space of time, and the arm flies swiftly through its traverse. The passing of the tappet leaves the shaft at the point of the stroke. Here comes into play the spring on the neck of the picking shaft; stretched by the turning away of the shaft, it draws the shaft back again, as soon as the impetus has spent; the picking arm on the end of the



Front View of Tappet

Side View of Tappet

Fig. 322

shaft returns to the inactive position, and the picking strap again falls slack to the picker.

Over-pick Motion. — The average weight of a full shuttle in a cotton or other light loom is from 10 to 12 oz., but a shuttle used for weaving woollens, heavy worsteds, and all forms of heavy fabrics is much weightier, amounting to as much as 4 lb. when full. To drive a shuttle of that weight across a space of 8 or 9 ft. requires greater power than the tappet and cone can easily give. On a rough calculation, to drive a 10-oz. shuttle through a space of 60 in. a force of 19 foot-pounds is necessary. Arguing upon that basis, for every pick on the broad loom, with the heavy shuttle we would require, we would need the enormous force of 200 foot-pounds for 200 picks per minute. We have rather understated than overstated the case; yet the problem appears sufficiently formidable.

Various inventions have been devised to drive the heavy loom shuttles; the type most general, however, is that known as the *high-topped*, and associated with the dobby looms. To begin with, this type of picking motion is driven by the loom crank shaft, and thus has the whole driving power of the loom at its back. This is an immense advantage in power, though other factors limit the weaver's satisfaction with the arrangement. Upon the crank shaft a tappet is pinned, the point or neb of the eccentric being a blunt cone. The gradation of the tappet point may be varied, according to the speed of pick desired; but for fast looms the point is almost straight. Additional velocity is derived from the shape of the appliance upon which the tappet acts. This is a bowl borne in the centre of a treadle geared directly under the crank shaft. Upon the picker treadle shaft the tappet acts. From the treadle a connecting rod extends vertically to a short lever on a horizontal shaft above the loom. A slot in the lever allows a measure of play to the connecting rod at its head. On the end of the shaft the picking arm is fixed vertically; from the end of the picking arm the picking strap is stretched to the picker in the shuttle box of the loom. A spiral spring catches into the picking shaft, steadying its movement, and bringing it back to the normal position after the stroke of the tappet has been spent.

Of course there is a set of these appliances at each side of the loom. Unless regulated in some way, the tappets, being on the crank shaft, would both act at every pick. We might place the points of the tappets in diametrical opposition to each other; but that method would only divide the pick between the two tappets, and cause a useless double

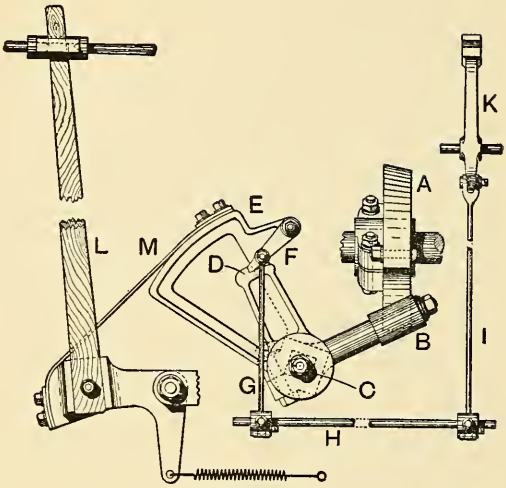
action. By an ingenious arrangement the difficulty has been overcome in the multiple shuttle-box looms; the links in the box chain control the picking treadles or levers. One link on the chain causes the treadle at the right to move its bowl out of touch with the tappet, and at the same time brings the tappet and bowl on the left into contact. An alternate picking motion is thus effected, one pick for every revolution of the crank.

Action of the Over Pick.—The over-pick motion resembles more nearly than any other the action of the hand-loom weaver. The picking shaft is horizontal, and moves in a horizontal direction, backward and forward, impelled by the connecting rod extending from the picking treadle to the lever on the picking shaft. Unlike that of the cone picking motion, the picking arm is vertical, the strap connecting it and the picker closely resembling in direction and action the cords on the handle and picker of the hand loom. The quick oscillation of the picking shaft sends the arm forward, jerking the picker swiftly, and striking the heavy shuttle across the loom.

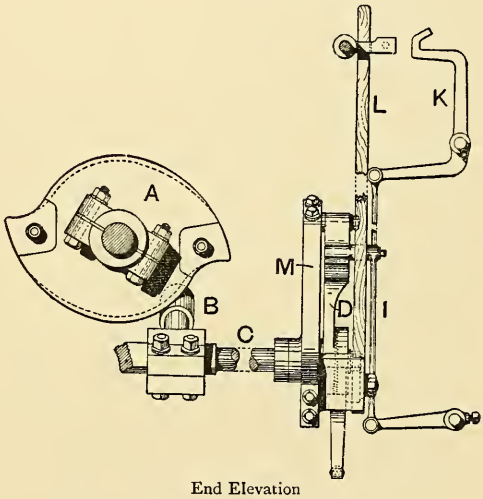
From the description given of the alternating action produced by the box chain upon the treadles of this picking motion, it is easy to infer that the picking may be regulated according to design. If it is desired that several shuttles from one side of the loom should be sent through in succession, the links of the controlling chain are altered to suit. In fact the over-pick motion is one of the best for pick-at-will looms.

Under-pick Motion.—From one point of view, the under-pick motion is the most advanced contrivance; it is more compact and fits into the general mechanism of the loom more closely. The whole appliance is within small compass, and operates immediately under the shuttle boxes. A casual observer would conclude that the only difference between the under-pick and the most common of the over-pick motions is the conversion of the picking shaft into a picking arm. If this could have been done, much trouble would have been saved; but, unfortunately, mechanics have to deal not with abstract things but with very hard and stubborn materials. The principle of the cone-pick motion has been utilized in some of the under-pick appliances now in use; modifications and improvements have been introduced, however, which constitute the latter a distinct class. Like the tappets of the cone pick, the cams of the under motion are fixed on the low shaft of the loom; but the tappets are double-nosed, and resemble rather a warp-shedding tappet than a common

picking tappet (fig. 323). The cone is placed directly under the tappet, receiving a downward blow. Upon the head of the short shaft corresponding to the picking shaft of the over-pick motion a leather strap is bolted. The latter shaft, however, is in two parts. Upon the same fulcrum, and coming up above the head of the lever, another is loosely placed; from this lever comes a ratchet pin which joins the two together. The second lever forms the head of the double shaft, and upon it the leather strap is bolted. The other end of the strap is firmly pinned round the projecting head of a three-armed lever, the fulcrum of which is the rocking shaft. The wooden head of the lever penetrates a slot in the bottom of the shuttle box, and acts upon the picker.



Front Elevation



End Elevation

Fig. 323.—Under Pick Motion for Power Loom

A, Double-nosed picking cam. B, Cone. C, Horizontal rocking shaft actuated by the cone. D, An arm, terminating in a stop D, set on the rocking shaft at right angles to B. E, A second arm loosely mounted on C, carrying a short lever or catch, F, which is held against the stop of D, except when there is a shuttle in the opposite box, when it is lifted out by means of levers G, H, I, K, the last of which is in contact with the shuttle-box swell. L is the picking lever, actuated by the arm E through the leather strap M.

On other looms the lever, which may be called the picking arm, is threaded through a spindle parallel with the shuttle box, with a picking point fixed upon it. To the lower arm of the three-armed lever, round the head of which the strap is pinned, a spring is linked. When the tappet strikes down the cone the picking lever is elevated; it draws the strap, which, acting on the projecting head at the base of the picking arm, causes it to spring forward,

striking the picker in the shuttle box. After the force of the tappet blow has been expended, the spring draws the picking arm back into the vertical position.

As there are two motions, one on each side of the loom, both cannot operate at once. Nor is there any way of throwing the tappet out of gear. Here we find the reason for the bipartition of the picking lever. A latch holds the two parts together when the shuttle on that side is being driven; the latch is released when the shuttle on that side is to remain still. Upon the point of the latch a rod acts. Following the direction of the rod, we find that it descends vertically to a light rod fixed in the frame; from thence, in the form of a strong wire, it passes right across the loom, where it joins another vertical rod, connected with the stop rod, and a finger attached. The finger is in contact with the swell in the shuttle box. Observe the action. When a shuttle is in the box it acts upon the swell, sending the finger back; the finger depresses the rod; the force passes on to the wire which carries it across the loom to the latch on the other side, lifts it, and causes the picking shaft to fall in two, the upper end with the picking strap losing contact with the lower half operated by the tappet. So long as there is a shuttle in the shuttle box the picker opposite cannot work. Both sides are the same. If, for example, a shuttle is in the right-hand box, the latch on the left-hand picking shaft will be lifted, and the lower arm of the picking lever idly move to and fro. In equally effective fashion the left-hand shuttle box acts upon the right-hand picking appliances.

Lever Under Motion.—There are many forms of under pick, the motion seeming to suggest possibilities greater than any of the other motions. One of the most popular of under-pick motions is the lever, operated upon the tappet and treadle principle (fig. 324). The fulcrum of the treadle is on the back frame of the loom, while the point falls into a slot in a bracket on the foot of the picking arm. The fulcrum of the vertical picking arm is on the rocking shaft; its base is held by a strap linked into a spiral spring, the other end of which is held to the frame of the loom; the head of the shaft, which is usually composed of wood, passes into a slot in the bottom of the shuttle box, and acts upon the picker there. A plain round tappet, with a bowl in its centre, revolves with the low shaft of the loom, and acts on a bevelled plate covering the upper surface of the treadle. The construction of the picking plate proceeds upon the same principle as the formation of warp-shedding and picking tappets. The aim in

forming the plate is to obtain a short period of gradual pressure from the tappet bowl, a sharp stroke, and then a short gradation after the stroke. By this formation we obtain the greatest force available for the picking stroke, while avoiding jerking of the treadle.

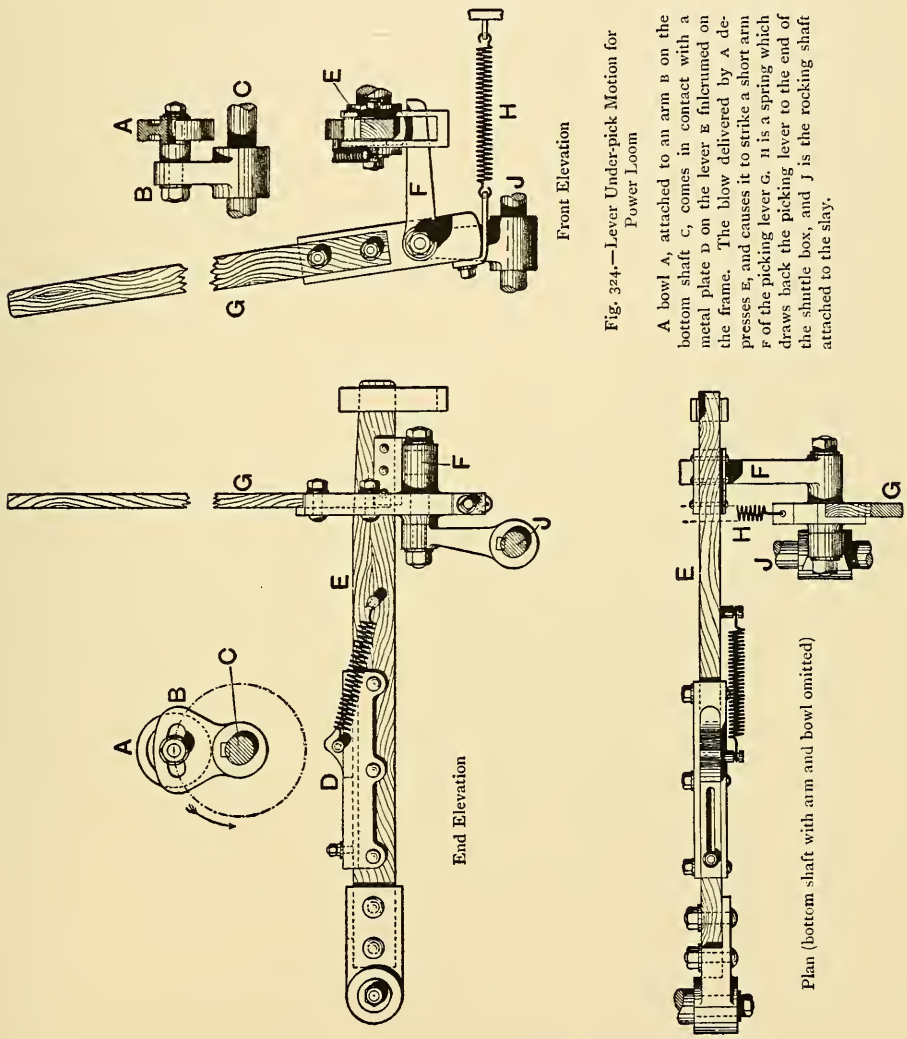


Fig. 324.—Lever Under-pick Motion for Power Loom

A bowl A, attached to an arm B on the bottom shaft C, comes in contact with a metal plate D on the lever E fulcrumed on the frame. The blow delivered by A depresses E, and causes it to strike a short arm F of the picking lever G. H is a spring which draws back the picking lever to the end of the shuttle box, and J is the rocking shaft attached to the slay.

Like the other motions described, the lever under pick is controlled by some kind of mechanism designed to change the pick from the one side to the other, though it is seldom applied to single-shuttle looms. A chain with low and high links upon a star wheel may be employed to lift off and on the gearing of the picking plate. Or

it may be an extra hook is put upon the Jacquard, and the picking operated in conjunction with the warp shedding; but none of these appliances involves any new principle; in any case they are simple extensions of either the chain tappet or the Jacquard appliances.

Multiple Shuttle Boxes.—Change of colour and yarn is as necessary in weft as it is in warp, if pattern is to be produced. For the hand-loom weaver no problem exists in the way of changing his weft as the pattern requires. He assembles all the shuttles required upon the shuttle board, and regularly changes one shuttle for the other, in proper turn. Many changes limit his speed and call for swift dexterity, but that is a matter of craftsmanship. As far as possible, the skill of the operator is limited to minding the machine in the power-loom factory; to change shuttles on a power loom running at the rate of 160 picks per minute, without stopping the loom, would be an impossible task for any weaver, however dexterous.

Before the power loom had been invented, however, a method of changing shuttles automatically had been devised by Robert Kay, son of the inventor of the fly shuttle. He put two shuttle boxes on the end of the slay, attaching to them levers and springs which the weaver operated to call up the shuttle box required. Kay's invention, mechanically improved, is still in use on the hand loom, and illustrates in a general way the principle of multiple shuttle boxes.

Spring Shuttle Boxes on the Hand Loom.—Instead of being part of the slay, as on the ordinary loom, the double boxes are separate pieces fixed to the end of the shuttle race (figs. 325, 326). The boxes rise and fall on a pair of vertical spindles, held in the top and bottom boards of the apparatus frame. Two rods joined at the head by a spring come up from the bottom board and work in a slot made in the centre of the top board; upon these rods small brackets project, catching into corresponding projections on the boxes, and holding them in position. From each box a pair of cords or straps, joined like a handle at the centre, are connected with lifting levers. At the interior ends of those levers cords are joined to a lever passing to the other side of the loom, and also to a lever fulcrumed on the slay, the free end of it projecting above the hand tree. By pressing down the lever, the weaver lifts the boxes. On the hand tree itself a small trigger projects, the inner end of which is connected with the spring rods upholding the boxes; pressure upon the trigger draws the rods together, letting the boxes drop by withdrawing the steps upon which they are supported. Though mechanically efficient, the apparatus has no power

of action. As pointed out, the lifting levers are attached to a lever passing to the other side of the loom; at the end of this lever we

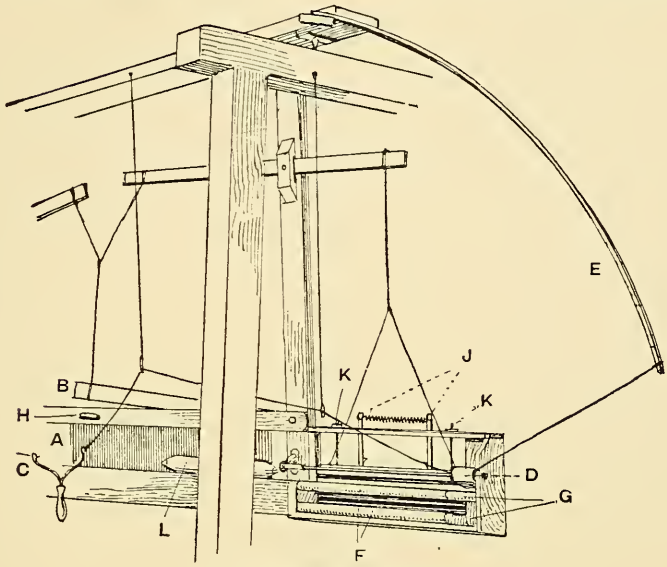


Fig. 325.—Spring Shuttle Box

A, Reed. B, Lever lifting the shuttle boxes. C, Picking stick. D, Picker. E, Spring returning the picker to the end of the box. F, Sliding portion of shuttle box. G, Fixed portion of shuttle box. H, Trigger which draws apart the rods J, allowing the sliding portion of shuttle box to fall. K, Guide rods. L, Shuttle.

find a weight and balancing contrivance which bring force to bear upon the levers and lift the boxes when the changing lever is brought into play. Having his hand on the slay cap, the weaver has only to employ his forefinger for lifting and his thumb for depressing the shuttle boxes.

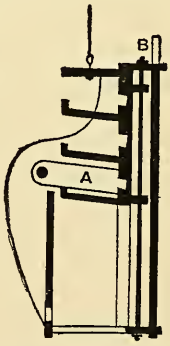


Fig. 326.—Section of Drop Box for Three Shuttles

A, Picker. B, Rod on which the box slides.

Methods of Actuating Multiple Shuttle Boxes on the Power Loom.—Dr. Cartwright tried, by means of a movable tray, to change the shuttles automatically on the power loom; but his invention was as nearly a failure as the contrivance of a mechanical genius could well be. Excepting as a curiosity it has no existence. Since then numerous inventors have applied their minds to the problems involved, and numerous inventions have been produced. A peculiar and, to the operative, tantalizing feature about shuttle-box mechanisms is their small differences in detail. One inventor adopts chains, another substitutes lags, and another brings in needles at one part of the shuttle-changing apparatus; others reverse

the levers which have been working on some form of machine. The only way to get over the difficulty presented by such variation in detail is to try to get a clear view of the main types of shuttle-box motions, and leave the further characteristics for practical study in the factory.

Shuttle-box motions are generally regarded as being of four types: 1, *the link or chain motion*; 2, *the lag-and-peg motion*; 3, *the bowl or pulley-and-rod motion*; 4, *the circular-box motion.* Excepting the last, these motions are combined in some machines, or so adapted and modified as to leave one undecided which class they can be placed in. However, as we deal with the main principles of all the motions, that fact interferes in no way with our plan.

The Link-box Motion.—Like the chain-tappet warp-shedding apparatus of which it is a derivative, the link-box motion consists of two distinct parts, the chain and tappet gearing and the mechanisms which transmit the motions to the shuttle boxes. For clearness, therefore, we shall examine them separately.

1. The whole machine may be described as two extremes and a centre. The two extremes are the chain with its links on the chain barrel, and the shuttle boxes, while the centre and medium between the two is the set of cams on the loom shaft, governed on the one hand by the chain, and directing on the other hand the lifting and dropping of the boxes. We note the chain and its connections with the tappets first (fig. 328).

As we have said, the cams or tappets are the centre of the whole motion. These are carried by a disc having a lateral and rotatory movement upon the crank shaft. The disc, with its tappets, moves upon a sleeve, firmly pinned on the shaft, groove and projecting pin effecting a rigid sliding connection between them. Acting upon the disc like a finger, a lever extends vertically from a bar above, forming its fulcrum. Above the fulcum the lever is continued, in a curve, against the head of which a spring on the fulcrum bar presses. From the top end of the lever another lever lies at right angles till it joins another lever at right angles with it. The point of this last lever is bent over, and rests above a chain and barrel. Driven by the mechanism of the loom, this barrel revolves, and causes the chain to move round link by link. It is obvious that the links on the chain determine the lift of the lever resting upon it, and through that lever the finger on the disc and tappets will be moved. A high link will cause the tappets to move the full length, and a lower link imparts a movement less extensive. If no pressure is put upon the lever

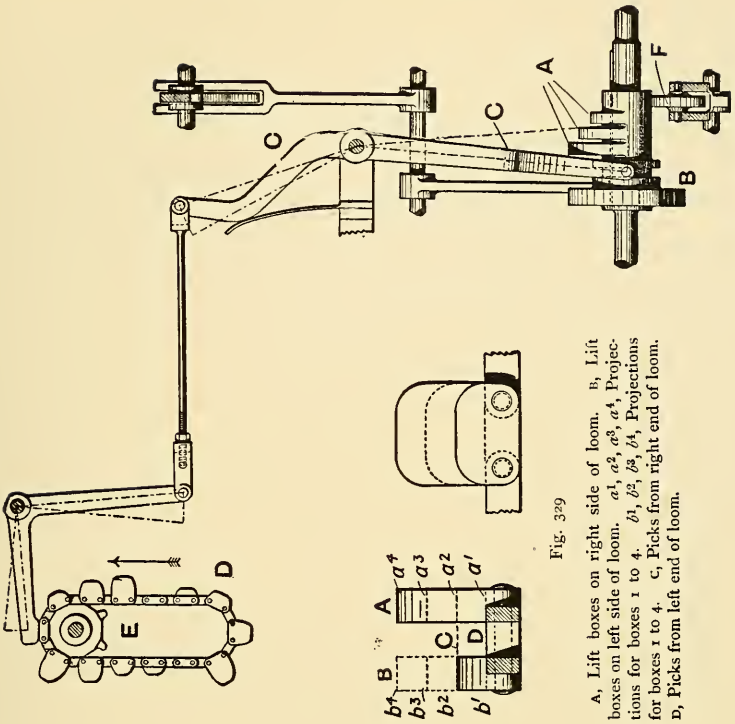


Fig. 328

A, Tappets or cams. B, Disc. C, Finger lever from box chain. D, Chain. E, Barrel. F, Bowl on tappet treadle.

Fig. 329

A, Lift boxes on right side of loom. B, Lift boxes on left side of loom. a^1, a^2, a^3, a^4, Projections for boxes 1 to 4. $b1$, b^2, b^3, b^4, Projections for boxes 1 to 4. C, Picks from right end of loom. D, Picks from left end of loom.

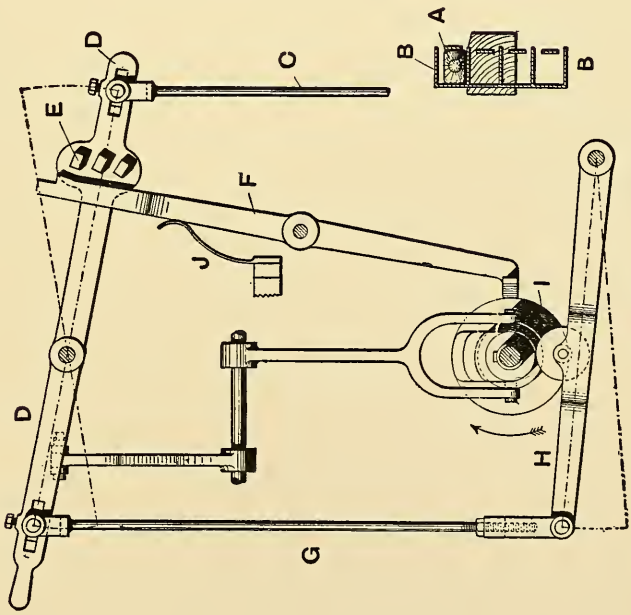


Fig. 327

A, Shuttle. B, Shuttle boxes. C, Lifting rod. D, Lifting lever. E, Pegs of drop box. F, Drop-box lever. G, Link of lift. H, Tappet treadle. I, Disc with tappets. J, Spring.

resting upon the disc neck, the spring will act, bring the lever back to the perpendicular, and cause the disc to resume its first position.

2. Under the cams on the disc, and out of touch with them when the disc is at rest, that is, unmoved laterally by the finger lever, we find a horizontal lever, with a bowl in the centre, like a treadle (fig. 327). From the farther end of the treadle a rod connects with a lever operating the boxes. If a finger actuated by a link on the chain brings a particular tappet forward into connection with the proper bowl and treadle, it follows that the shuttle box designed will be lifted; the tappet presses the bowl down, the connecting rod draws down the outer end of the shuttle-lifting lever, and elevates it at the inner end. The action appears very simple and exact.

Some provision has to be made, however, for the dropping of the boxes. For this purpose a vertical lever, with a notch on its end, fits into the projecting points on the lifting lever (fig. 327). The lower end of the lever is curved towards the disc and tappets, but it cannot touch them so long as they are at work (fig. 330, *a*, *b*, *c*). When the disc comes back to the end of the sleeve, having been relieved from action for the moment, it touches the vertical lever supporting the lifting lever, knocks it aside, and compels it to lose hold on the projection, with the consequence that the shuttle box must drop down.

In thus sketching the principle of the motion, we have necessarily left out of view some of the duplications and minor parts of the apparatus; but these differ somewhat in various makes of the motion, and particulars of one would not be found true of another.

Lag-and-peg Motions.—The more deeply we enquire into multiple shuttle-box motions, the more evident the likeness between them and warp-shedding motions appears. Very early in the history of this part of the power-loom mechanism that likeness was observed, and soon came to be utilized. Combinations of shedding and picking, or, at least, shuttle-changing motions, have naturally been adopted. One of the first to combine the motions was the dobby. In addition to the lags for warp shedding, lags for changing the shuttle boxes were inserted in the chain. When this has been made clear, little remains to be said about the general structure.

A slight sketch, however, may be given of the method by which this motion operates the shuttle boxes. Two principal levers are employed, one for each series of boxes. For a four-box loom the levers carry two smaller levers, arranged to act indirectly through the

agency of the main levers. For example, if a peg were to strike the outer small lever, it would impart one-third of a complete movement to the principal lever; if, on the other hand, the centre swing, or small lever, is struck, it gives two-thirds of a complete movement to the lever. In order to perceive the effect of these gradations of motion, it is necessary to examine the whole action of the principal lever, and what a complete motion really means.

To the end of the principal lever, if we consider only one of the two for the moment, a connecting rod is attached which terminates in a lever working up and down on the crank shaft. By its action the lever causes the vertical lever to move to and fro. If the principal lever, therefore, swings full, the latter lever will oscillate the full length of its traverse. What this means can be seen by looking at the upper end of the vertical lever. Here it comes into contact with a pair of racks, its head being toothed to engage them. Working between the two racks is a cam on the end of a short neck fixed near the end of a lever, from the other end of which a pulley and block works the set of chains attached to the levers which directly lift and drop

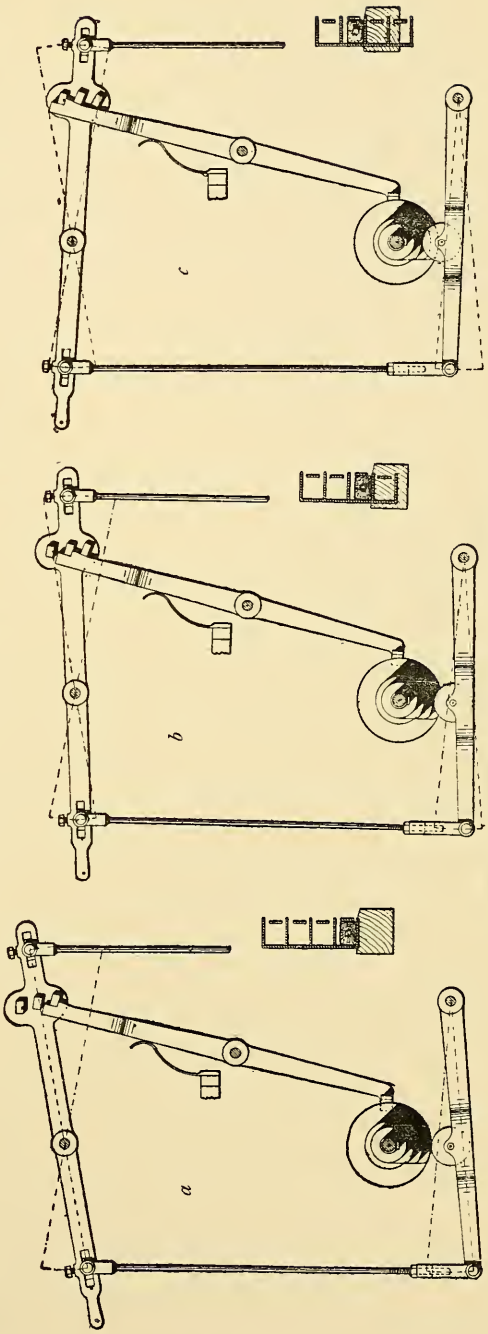


Fig. 330.—The Three Positions of Levers and Shuttle Boxes

the shuttle boxes. The latter are named *balance levers*, and are three in number. Within slots in the centres of these levers small pulleys, turned at an angle to lie in the direct line of the same chain, hold the chain coming from the lever operated by the rack and pinion.

Now we are in a position to trace the whole action of this form of motion. Say that the peg of the dobby comes in contact with the outside small swing lever, then the principal lever only moves one-third of its possible motion, and imparts a correspondingly short traverse to the vertical lever acting upon the rack; by this it is brought into play against the second of the shuttle-box levers, and elevates it. On the other hand, if it is desired to lift the fourth box, then the whole three balance levers must be lifted together; in other words, the principal lever must act, sending the vertical lever the full length of the rack, pulling up the whole set of levers. The mutual interaction of the levers causes the boxes to rise and fall with regulated movement. A strong objection to drop boxes is thus removed. Some motions drop the boxes by mere gravity, and cause them to rebound with violence, injuring the boxes, and sending vibrations through the whole loom. No one who has not heard a shuttle box drop can realize what this means.

Rod-and-bowl Motion.—Though closely associated with what has been called the American dobby, this motion has been applied to a British warp-shedding apparatus working upon a similar principle, and patented in this country. For the moment, the shuttle-box changing gear may be viewed by itself (fig. 331). Upon a curved lever, the fulcrum of which is a pin in the loom frame, a thin round plate or wheel, toothed in two sections, with divisions between, and slotted through one-half of its inside circumference, is loosely pinned, its revolution in either direction being limited by a stud on the lever catching into the slot. On the solid part of the thin wheel the end of a lever is pinned, forming the connection from the wheel to the lever upon which the chain controlling the motion of the shuttle box is firmly bolted. On the under and upper sides of this vibrator, as the wheel plate is named, two other thin wheels revolve, toothed one-half of their circumferences. The vibrator may be brought into contact with either the top or bottom toothed wheel by the lifting or dropping of the lever holding it. The instrument by which this movement is effected operates under the lever in the shape of a rod-and-bowl chain upon a barrel in the centre of a pinion wheel driven from the crank shaft. Suppose, for example, a plain link of the chain is passing under the lever. The vibrator sinks, and comes into contact

with the teeth of the wheel under it, which pulls it round to the limit of the slot, drawing the end of the connector away from the lever

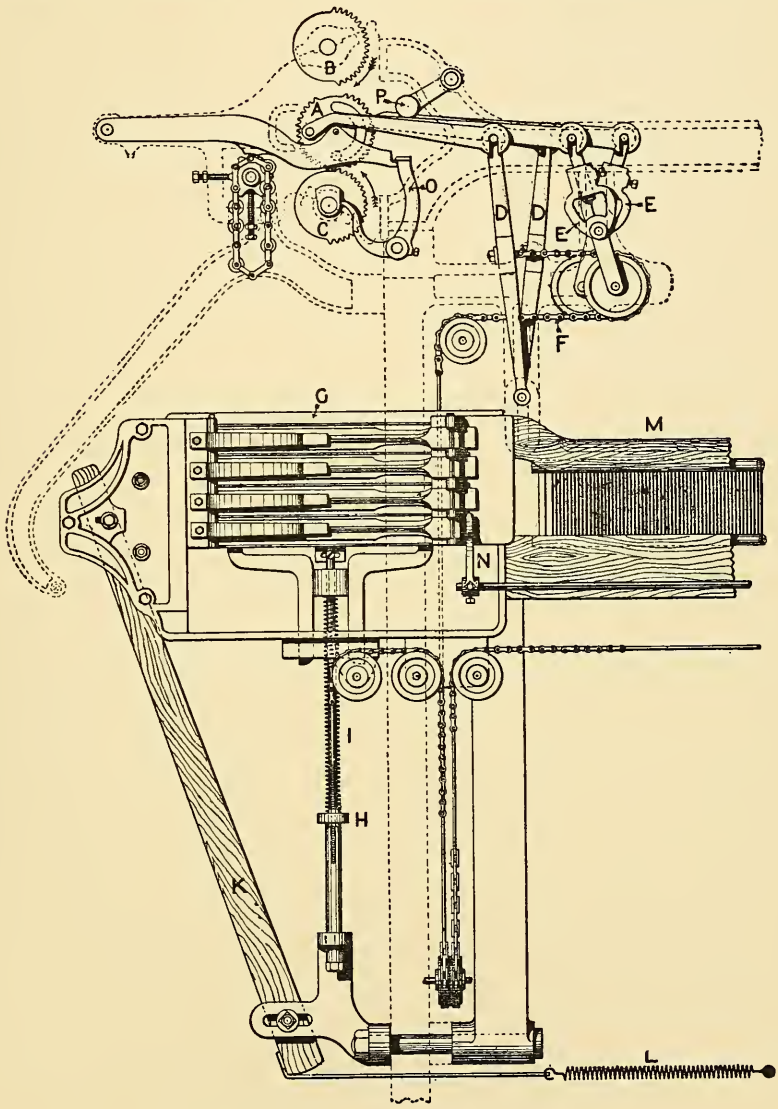


Fig. 331.—Rod-and-bowl or Knowles' Chain Shuttle-box Motion

A, Vibrator. B, Upper cylinder. C, Lower cylinder. D D, Simple levers. E E, Compound levers. F, Chain to lift boxes. G, Shuttle-box frame. H, Lifter plate. I, Spring and shaft on which boxes are raised. K, Picking arm. L, Spring of arm. M, Stay. N, Box check. O, Lock knife. P, Weight.

holding the chain, with the effect that the chain is drawn and causes a motion of the shuttle boxes, the nature of which need not be precisely defined at present.

This action appears to effect a change on one lever; but the fact is really different. Working on the same shafts and gearing, we find another lever and vibrator; attached to this is still another lever, upon the end of it a pulley round which the chain from the first lever also passes. Given that the links on the box chain actuating

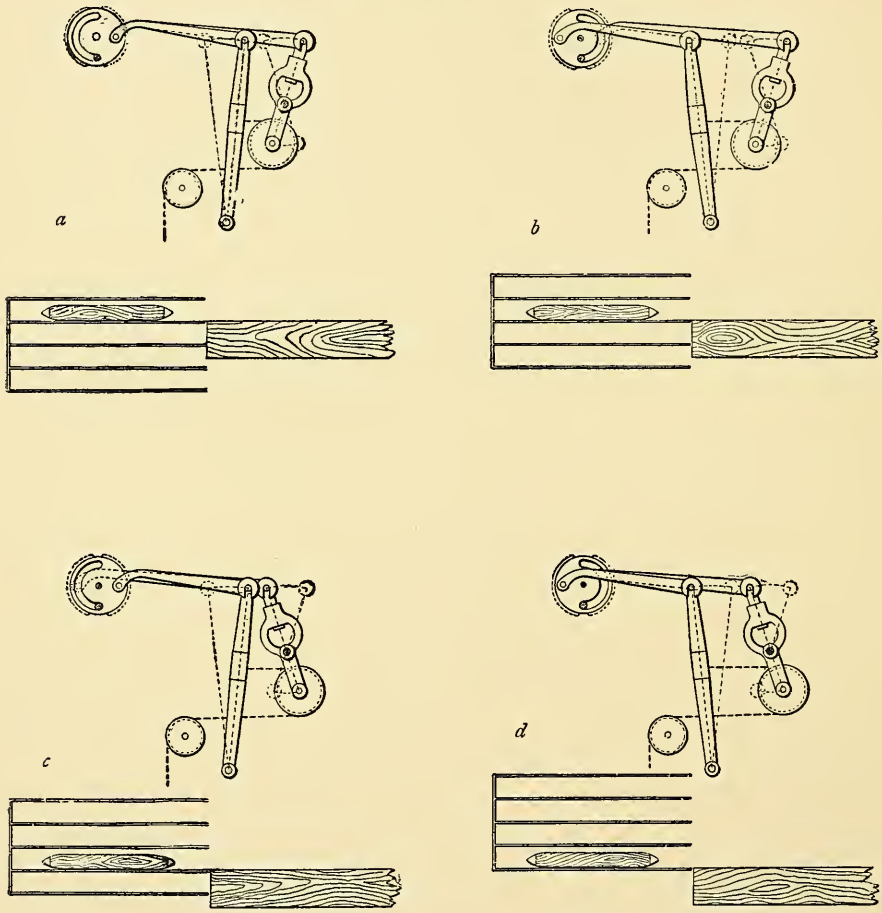


Fig. 332.—Knowles' Chain Shuttle-box Motion for Four Boxes. Diagram of the four positions

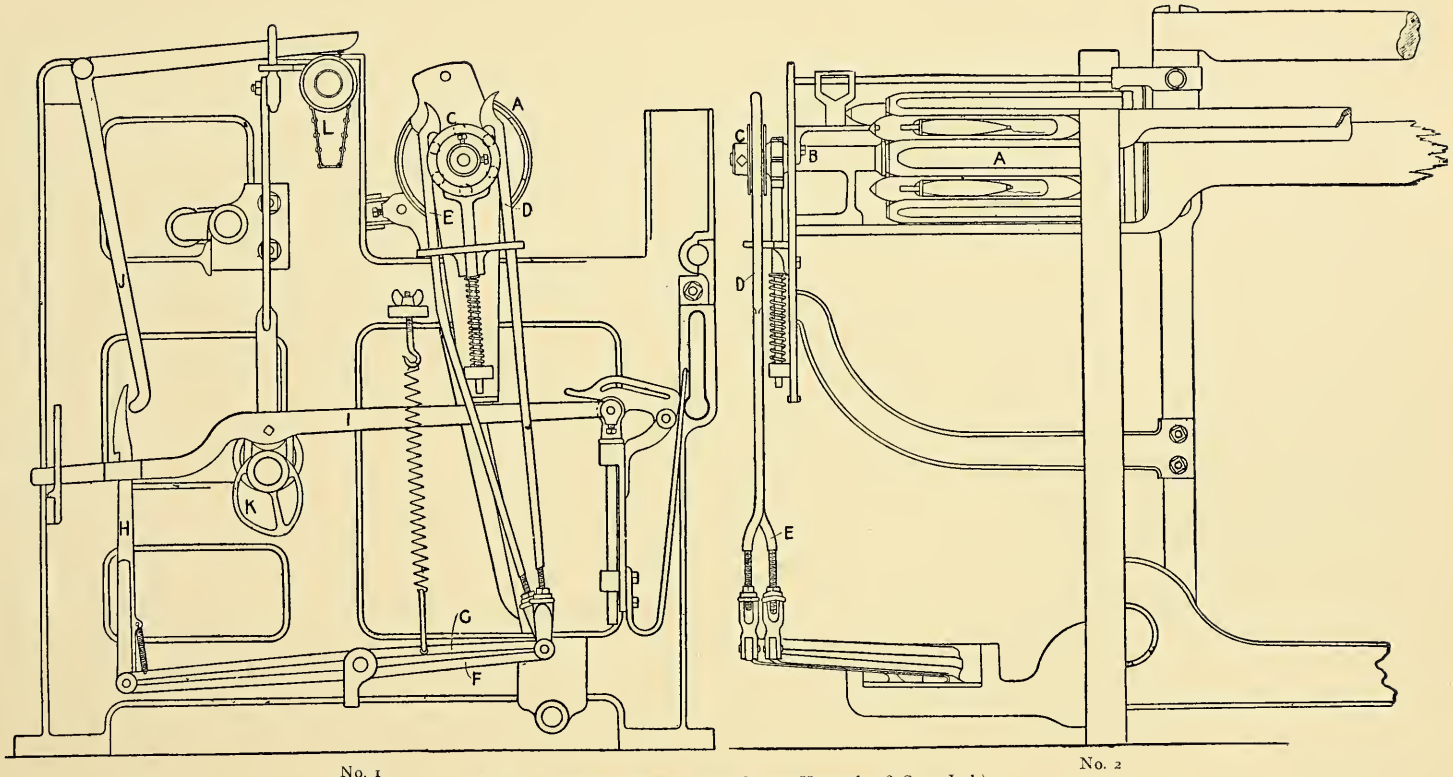
both levers happen to be the same, viz. plain links, then the heads of the connectors will be on the same level. No lift can occur in this case, and the top box will remain at the level of the shuttle race (fig. 332, *a*). Let us suppose, however, that the vibrator of the first lever is pulled round, while that of the compound lever is stationary; then the second box will be lifted, because the box chain is pulled to that degree (fig. 332, *b*). Reversing the motion, and turning the one

to the left and the other to the right, by elevating the first lever and vibrator on a bowl in the chain, while that of the compound lever is acted upon the opposite motion, the third box will be lifted, because the pulley on the compound lever has moved out, and drawn the chain controlling the lifting of the boxes double the length of the former motion (fig. 332, *c*). When both vibrators have acted, lifted by bowls on the box chains, and the connectors have been brought level, but at tension, the fourth box is lifted up to the level of the shuttle race, the whole of the controlling chain having been used (fig. 332, *d*).

Two sets of gearing and other appliances are required for operating four boxes on each end of the slay; six shuttles may be operated by three sets. "The principle of this motion", says a writer, "may be defined as that of two levers with arms of different lengths to produce three lifts, the short-armed lever effecting the first lift, the long-armed lever the second lift, and the two, when combined, the third lift (fig. 332). The advantages of this system of shuttling are important. Firstly, the chain is simple to construct, for there is only one height and shape of bowl, and not several, as in the use of links; secondly, the boxes, like the healds, are elevated gradually; thirdly, rising on a spring, they may be pressed down by hand, and yet, when released, they will return to their proper position."

Revolving Shuttle Boxes.—For any number of shuttle boxes greater than four the circular box motion is the best. A wooden cylinder contains the shuttles in boxes compartmented and dividing the cylinder into equal parts. Six-shuttle cylinders are most common, but we have seen as many as eight shuttle boxes, and there is little to hinder ten or twelve shuttle boxes being formed in a cylinder. In principle all forms of revolving shuttle-box machines are very much alike and involve no different problems, though the parts are numerous and complex.

A six-shuttle cylinder is divided internally into as many compartments (fig. 333). A disc plate is fitted on to the centre spindle of the cylinder, and from the disc six equally spaced pegs project. Within the circle of the pegs, and also on the spindle, a star wheel is fitted, with a spring pressing on its under side, to hold the shuttle boxes steady in place, while permitting them to move round when required. Upon both sides of the pegged disc two drawing hooks are forced by flat springs on their outer sides into contact with the pegs. The shafts of the hooks bend down to a pair of levers, each having a fulcrum pin near its centre. To the other ends of those horizontal levers, resem-



No. 1 No. 2

Fig. 333.—Revolving Shuttle Box (George Hattersley & Sons, Ltd.)

1, Side elevations, showing levers and box chain. A, Revolving shuttle box. B, Spindle of the mechanism. C, Revolving disc, with pegs corresponding to the shuttles. D, Drawing hook. E, Drawing hook. F, Lever of drawing hook. G, Lever of drawing hook. H, Pair of vertical hooks connecting drawing hooks with lifting levers and box chain. I, Lifting levers. J, Hooked lever from box chain. K, Cams acting on lifting levers. L, Box chain.

2, Front elevation, showing shuttles in revolving box. A, Shuttle box, with shuttles. B, Spindle carrying mechanisms. C, Revolving disc. D, Drawing hook. E, Drawing hook.

bling treadles in form and action, long hook levers are attached, the hooks passing through slots in a vertical and a horizontal lever. Before work is started, the hooks rest on the horizontal lever. The fulcrum of the latter is at its end in the front framing of the loom; but just above the shaft of the loom it carries a bowl which comes in contact with a cam on the shaft, the cam causing the lever to oscillate and lift up and down. It is evident that, if the hooks keep hold of the horizontal lever, they will be lifted and pull down the hooks on the cylinder disc, drawing it round. Here, however, another set of mechanisms comes into service. The cam must always revolve, because fixed on the loom shaft, but the cylinder may not be required to revolve; indeed it must not when the same shuttle is being employed in making successive picks. The vertical lever we noted as slotted on the levers or hooks coming up from the treadles acting on the cylinder hooks and pegs, is bell-cranked, and the end of the horizontal arm is over the feelers of the box chain in the loom. We see that if this lever is lifted by the feelers, it will send the hook of either of the treadles out of gear and into the open slot on the lever moving up and down with the cam on the loom shaft. The gearing has several parts which must be closely observed. First, we note an eccentric cam on the shaft beside the cam mentioned above, and coming down into touch with it is a foot-shaped base of an upright lever, upon the head of which the box chain is mounted. The two feelers come down from the levers aforementioned, and rest on the chain passing round the cylinder. The cam at the foot of the lever supporting the box chain lifts it up into contact with the feelers on the lever. If the chain is solid it lifts the two feelers right up, and the bell-crank lever slotted on the connectors of the treadles sends the hook out of gear upon the horizontal lever acting upon the revolving cam. The lever moves up and down, but the hooks of the shuttle-box cylinder do not move. A low link in the chain occurs; then one of the feelers is not lifted; the hook of the treadle corresponding remains clutched into the horizontal lever, and is drawn up, causing the legs of either hook on the disc to respond by pulling round the shuttle-box cylinder. Another shuttle comes into the level of the race. We have two hooks and two levers and gearings, and thus are able to move the shuttle-box cylinder either from No. 1 to 2, or from No. 6 to 5. The variation possible, therefore, covers the whole six shuttles, given that the next shuttle is one of three. We may make 1 succeed 2 or 6, 3 follow 2 or 4, 4 succeed 3 or 5, and the reverse

of these in order. Further, any shuttle can be made to pick any number of shots. This gives the designer a fair range; for that reason we require chains and a cylinder to govern the motion.

Skipping Revolving Boxes.—A natural corollary of the revolving shuttle-box cylinder is the skipping-box cylinder. Several contrivances have been devised to give effect to the idea in an original way; but the most commonly employed are those which are little more than obvious modifications of the ordinary revolving shuttle-box apparatus. By adding to the number and varying the sizes of cams and feelers and levers, with appropriate box chains or cards and cylinders, the skipping change has been easily effected.

Advantage of Revolving Boxes.—The cylinder, when otherwise practicable, is always the motion which gives the best mechanical return for power. The absence of rebound, too common in even the best forms of drop boxes, is a clear advantage in the circular boxes. The movement being rotary, the speed of the loom can be maintained all through the changes, and, all the weights being evenly balanced, the driving power is constant and even. On heavy looms the revolving boxes have not been of so great advantage; but for light cloths, of fancy pattern, they have become quite indispensable.

Swivel Weaving on the Power Loom.—What the lappet is in warp shedding, that swivel weaving is to picking. Figuring is made in the former case with extra warp, and in the latter with extra weft. Swivel weaving produces finer figures than lappet shedding. It is found, however, that, on the whole, swivelling is a costly method of forming figures. Inventors have laboured vainly to bring the motion within the ordinary mechanisms of the loom. On that account much swivelling is still done on the hand loom, the difference of the cost between hand and power being so small that, hand production being more artistic, the power-loom manufacturer has no great temptation to compete. One fact, however, has to be taken into the account, and that is, the declining supply of hand-loom weavers. Whether we like it or not, weaving is fast becoming an obsolete handicraft, excepting for special fabrics made for a special market. Cloths which sell at twelve shillings the yard can never be popular when cloths almost equal in every respect can be sold for half the money. We hope that the handicraft of weaving will never wholly disappear, but even a reasonable optimism may only base itself on the special and artistic market. Only one other support for the handicraft exists in the pattern-weaving departments of the large manufactories. Signs are not

SWIVEL CLOTHS

(By J. H. Young & Co., Glasgow)

wanting that this refuge is becoming smaller; but it will probably outlast another century at least.

Swivel Shuttles and Mountings.—In the section on the hand loom a slight sketch was given of the swivel shuttle and its mountings, but we must examine more closely into the construction, because of the action of the mechanisms of the power loom. The shuttle itself is a small conical case containing a spool threaded on a spindle in the middle of the case (fig. 334).

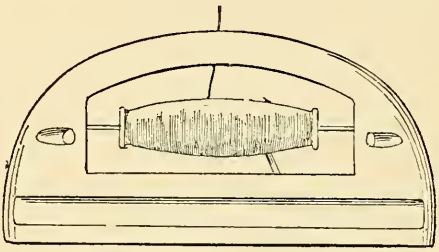


Fig. 334.—Swivel Shuttle of Ribbon Loom

Inside the small shuttle we commonly find very complex tension gears, for the purpose of regulating the output of weft yarn. Two glass rings are secured to spiral springs at opposite sides of the shuttle eye. Threaded through both rings and eye, the weft is kept in regular tension by the springs. On the upper edge of the shuttle a rack of small teeth is secured in a groove (fig. 335). A parallel groove is cut to receive the lip of the swivel frame, extending across the reed space on the slay, and resting against the slay cap (fig. 336). Behind the swivel frame a thin metal plate is fixed, with a support on its lower edge for the under side of each shuttle. The swivel board, it may be added, is slotted to permit the warp to be brought into close contact with the swivel shuttles. Upon the swivel board a series of pinions are carried, and placed over the shuttles, so that the teeth on the lower side may engage with the teeth of the

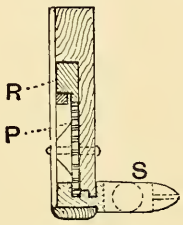


Fig. 335.—Section of Swivel Frame

R, Rack. P, Pinion. S, Shuttle.

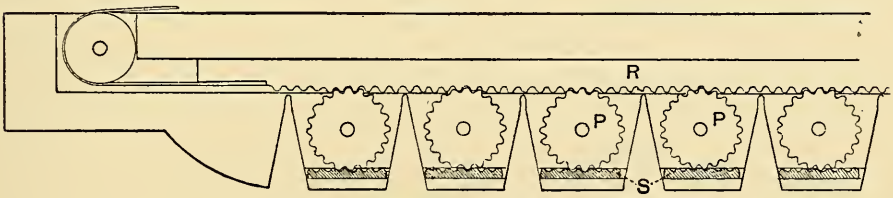


Fig. 336.—Swivels on Power Loom

R, Rack. P P, Pinions. S, Shuttles.

shuttle racks. Another rack extends across the whole slay, the teeth of which engage in the small pinions of the swivel board. The motion of this rack is lateral, and its action sets the shuttles in motion. Sup-

pose the rack moves to the right, it will cause all the shuttles to move to the left; if it passes to the left, the shuttles will return to their former holders. There must always be one more holder than shuttles. In many looms the action of the rack upon the shuttles is direct.

Being required when figures are being woven, and then only, the swivel shuttles are held up out of gear while ground weft is being woven. At the moment, however, when a series of figures are to be woven, the swivel frame is lowered, and the driving rack acts upon the shuttles, imparting to them the lateral movement necessary to cover the space between one shuttle and another. After the picks of figure weft have been inserted, another pick of ground weft is required; the swivel frame is therefore lifted, and the ground pick inserted. This done, the swivel frame again lowers and inserts its picks. This action is repeated till the whole figure has been formed. Here we obtain a clear glimpse of the most potent cause of the comparative slowness of swivel weaving. The one half of the loom must stand still while the other is acting, and that reduces the speed of, say, a 200-pick loom, to less than 100 picks per minute.

Several methods have been adopted for working the swivel on the power loom. One of the newest and most serviceable is that introduced by Messrs. Birchenough & Wood (fig. 337). The ground weft is taken off and put on by a clever adaptation of the lever picking motion. A star wheel is compounded with a four-winged cam, which acts on a bowl fixed in a cranked lever, which, in vibrating, moves the picking plates in and out of action. The peg wheel is mounted loosely on the crank shaft and slides freely in a lateral direction. The rotation of the peg wheel is obtained through two studs upon its inner face brought into contact with a disc rotating upon the loom crank shaft.

The lifting and driving of the swivel shuttles is effected by a complex series of contrivances which we must endeavour to analyse as briefly as possible. A cord from the spare hook of the Jacquard is attached to the projecting end of a lever, the fulcrum of which is in the frame of the loom near the picking shaft. As the end of this lever is lifted by the Jacquard hook, a bowl at the front of the lever bears upon a cam face formed on the boss of the peg wheel, and removes the pegs out of contact with the star wheel, stopping the action of the ground weft. At the same time, however, the bowl thrusts a projection from the peg wheel against a lever, the end of which is attached to a vertical lever slotted on to the holder of the

swivel frame, allowing the swivel frame to fall down. We have pointed to the sliding motion of the peg wheel, and, after the action described, it continues to slide on the picking shaft, sending one of a pair of studs into contact with projections on another disc fixed on the picking shaft, and imparting to connected cams a partial

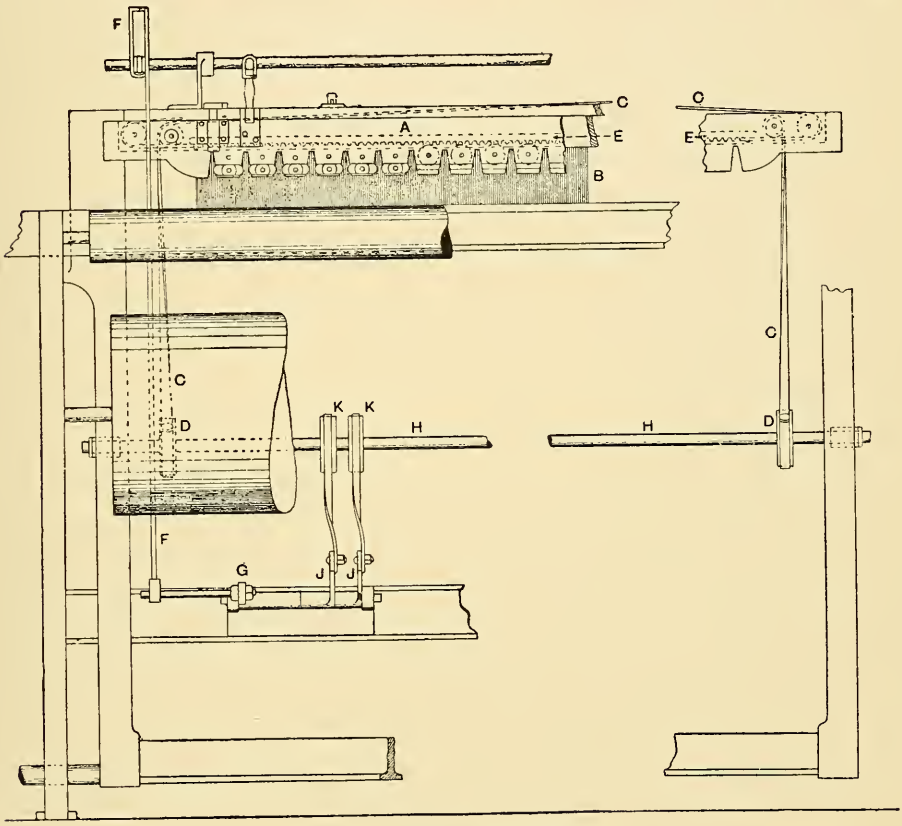


Fig. 337.—Swivel on Power Loom

A, Swivel frame. B, Reed. C C, Straps fixed on opposite sides of the pulleys D D, on the rocking shaft H, and to opposite ends of the rack E, giving lateral motion thereto. F F is a slotted rod driven by a cam acting on the arm G, and lifting the swivel frame A out of the shed. J J are treadles operated by tappets, and giving motion to the straps C by means of the pulleys K K, the shaft H, and the pulleys D D.

rotatory movement. From the cams, or one of them, the motion is communicated through a series of pulleys to the straps on the guide pulleys of the swivel frame. Thus the swivel frame is set in lateral motion and imparts the motion required to the swivel shuttles. The mechanism is capable of giving to the swivel frame a forward or backward motion, reciprocal pins and levers acting with opposed cams and springs to produce the action.

According to the method examined, it would seem that the figures made by the drop shuttles must always be in the one straight line; but the fact is not so. If the design requires that the figures be moved alternately, or in any order, to right or left, the starting point of the whole swivelling frame can be altered to the distance desired. Figures may be woven midway between those already made, or in a graded and diagonal line, or in any figure within the compass of the space.

As has been frequently pointed out, special and secret devices are practised in most weaving factories of high standing for swivelling and other purposes. The province of invention in weaving, especially fancy weaving, is by no means fully occupied by private devices, and still less by publicly patented inventions. It is for the man of ingenious mind to apply himself to devising new things, after he has fully mastered what is old and established and every way fundamental.

DESCRIPTION OF TAPE OR RIBBON MODEL LOOM

Tape or Ribbon Loom.—One of the most ingeniously contrived of weaving machines, the tape or ribbon loom exhibits in a novel shape all the principles of cloth-manufacturing mechanics. The loom is actually a series of little looms, all linked together, sharing in common the driving gears, but having each its own shuttle and warp. We have therefore no alternation of swivelling and cloth-weaving as there is on the broad loom. Here the swivelling is also cloth-weaving. Each warp and weft may be different in colour. Looms of the same kind fitted with the Jacquard admit of variation between one pattern and another along the whole length of the loom, weaving in a single loom as many as fifty ribbons wholly different in colour and pattern. For the purpose of presenting the swivel loom in whole, as a typical example of the structure and working of looms in general, we go over the mechanism in detail.

Every loom is divisible into four parts, viz.: 1, the warp shedding and control; 2, the weft motions and shuttling; 3, the beating-up motions; 4, the taking-up of the woven material and the letting-off of the warp. All four motions interact, but for the sake of simplicity we will detail each part by itself.

1. **Shedding Mechanisms.**—The heald shafts containing the healds through which the warp threads are passed hang supported by jacks fitted to the front of the loom frame. Wires or cords are passed round both ends of the upper heald shafts, and link into the hooks on little

blocks fastened to the jacks. The motions of the healds are caused by cords connected with the blocks of the hooks holding the cords by which the healds are suspended; for common tape-weave the cords are four in number, and each pair is held by a horizontal lever fulcrumed in the head frame of the loom. The lower lever carries at one end the cord of heald No. 1, and the other end the cord of heald No. 4. The cords of heald shafts 2 and 3 are similarly held in the ends of the upper lever. The same mechanism is, of course, at both sides of the loom. The horizontal levers are connected by square rods extending the whole width of the loom, a rod to each end of a lever. In the middle of the width of the loom the square rods are connected by belts or cords to treadle levers, which are depressed by a set of tappets geared on to the tappet shaft in the order required by the pattern being woven. The tappets only depress the treadles and lift the heald shafts; the treadles are recovered by springs, and the heald shafts are brought level again by means of weights attached to the lower heald shaft of each set of healds.

2. **Weft Motions and Shuttling.**—Like the warp, the weft is governed by a tappet-and-lever motion. A peg from the loom frame forms the fulcrum for the pair of jacks or levers, on the frontal ends of which a belt is hooked. The belt passes round the pulley acting upon the toothed ratchet which imparts the motion to the swivel shuttles. To the inner ends of the jacks belts are hooked, the belts extending to the base of the loom, where they are linked on to a pair of treadles fulcrumed on the back frame. The treadles are depressed by a pair of tappets fixed on the tappet shaft of the loom. As each treadle is depressed, it causes one end of the belt to be pulled by a jack, and thus drives the pulley of the swivelling ratchet.

In a normal specimen there are fourteen shuttles, but there may be as few as six or as many as fifty, one shuttle to each ribbon. The shuttles are hollow cones, and on the base of each a toothed wheel is pinned. The cone-shaped shuttle is set in the loom apex outwards, the base with its toothed wheel fitting into the ratchet contained in the cross bar of the lathe or going part. When the ratchet is driven from the pulley above described, it causes the shuttles to run to and fro, crossing with the contained weft the whole breadth of the ribbon or tape, inserting a shot or shoot of weft to be woven in by the crossing warp. Inside the hollow-cone shuttles, it may be added, the weft spools are carried, the letting-off of weft being governed by a little spring over the eye of the shuttle.

3. **The Beating-up Motions.**—The slay, lathe, or going part, as it

is variously named, is a rectangular frame formed by two sides or swords and a cross bar containing the sley or reed, the shuttles and shuttle mechanisms, and the "head". Driven by a crank from the main shaft of the loom, the lathe has a to-and-fro motion, going back to allow the warp to shed and the weft to shoot, and returning to beat up the weft and form the cloth. The fourth side of the square is the cross beam laid upon the head frame of the loom and slotted into it, forming the fulcrum of the lever motion of the lathe itself. The warp passes through the reed in the lathe and out round the breast beam in front of the loom, changing midway, by the combination of warp and weft, into the cloth form—either ribbon or tape.

4. **Taking-up and Letting-off.**—In the management of warp and cloth, the ribbon loom differs somewhat from the ordinary loom, and acquires thereby a special interest. The warps are merely derived from bobbins or cheeses, instead of being wound specially on a heavy warp beam. Each little warp is separate, and derived from a range of three bobbins set in a frame on the head of the loom. All the threads of every warp are combined on a roller at the base of the frame, and, turning round, pass upwards to what is called the "top castle" of the loom. Here are sets of pulleys fixed on horizontal rods. There are in all six rods or rows of pulleys, which must be carefully observed. Slightly elevated above the rest, the front row of pulleys is made up of sets of three, one large in the centre and two small at each side. The warp threads are passed round the side pulley, and pass thence on to the same order of pulley in the fourth row; passing downwards from this pulley, the warp goes round a suspended pulley held in position by a weight; from the suspended pulley, the warp is taken upwards again and round the second pulley of the fourth row and on to the third, but second small, pulley of the first row, and carried downwards through the back reed of the loom and on to the warp guide. From thence the warp passes through the healds to the sley or reed in the lathe, and thence to the cloth or breast beam. Its journeyings do not end there, but we leave it meanwhile.

The second warp passes on to the first of the second row of pulleys, passes over the same pulley on the third row, being taken, like the first, round a suspended and weighted pulley, and back in the same manner to the guiding reed.

It is obvious that these pulleys give tension and regulation to the warps, otherwise provided for on the warp beams of common cloth looms.

We now come to a very peculiar feature of this loom. The warp was left at the breast beam in the ribbon shape; but it does not end there. The ribbon or tape is carried back through the loom, round a turning beam, and up round the central large pulley of the front row of pulleys. It is taken along and round the pulley on the fifth row, down round a suspended and weighted pulley, and up again over a pulley on the sixth row. From this pulley the ribbon is taken down to the end of a peg arm, into which it is secured by a movable wedge or peg. The suspended pulley of the ribbon starts almost at the very "top castle" itself, and it drops down as the woven length of ribbon extends. When near the floor, the worker takes out the peg, draws the ribbon down into the box placed ready for it on the floor, at the same time pulling up the suspended pulley. The peg is wedged in again and work resumed till another length of ribbon requires letting off. We thus see how the tensions on warp and cloth are combined with letting-off and taking-on in the ribbon loom.

CHAPTER IX

Minor Loom Mountings

Minor Mountings.—Warp shedding and weft picking are the two functions of a loom. Minor appliances and gearings are added on to the loom to aid or supplement the operations of the principal motions. As standards of productiveness, both in speed and quality of fabric, have risen, these auxiliaries have multiplied. Many progressive manufacturers hold the opinion that the power loom has grown far too complex, and a movement has set in, the motive of which is to obtain greater simplicity in looms. By building special looms for given kinds of work, a simpler machine can be employed.

The main auxiliaries of warp and weft mechanisms in general use are: *Shuttle-box swell, shuttle guards, weft-stop, warp-stop, letting-off, and taking-up motions.*

Shuttle-box Swell.—Designed to serve chiefly as a stop motion in conjunction with the stop rod, the shuttle-box swell also helps to regulate the motions of the shuttle (fig. 338). The swell is a lever or spring, generally convex in form, set in the back of the shuttle box, reducing the width of the box at that part to less than the breadth

of the shuttle, when the centre is fully expanded. It is convex, and the ends do not lie in the path of the shuttle; it is a spring, or has a spring attached. Therefore the impact of the shuttle on entering can press back the swell and make room for itself. Driven a high speed and with considerable force, the shuttle is apt to rebound back into the race; but the elastic swell at once intercepts a part of its force and interposes an obstruction to its return from the box. The primary use of the shuttle-box swell, however, is to act as a stop motion in cases when the shuttle has not been driven across the warp, or when the shuttle stops short from any cause. Behind the swell is a spring, through which a short vertical lever is slotted; the base of this lever is curved and fixed to a rod extending across the loom, named the stop rod. A blade is fixed upon the rod at both ends. Corresponding to the blades, a pair of frogs or projections are screwed into the loom frame, set and shaped so that the blades and frogs dovetail into each other. So long as the shuttle continues to impinge upon the swell and so send back the small lever and lift up the blades in front, nothing happens; the blades always pass over the frogs. But if the shuttle at either end fails to act upon the swell, then the blades are driven directly upon the frogs, stopping the forward motion of the slay. This would entail severe shock upon the whole loom if no other provision had been made. We find, however, that the frog on the one side of the loom has a lever on its end which, when the frog is impressed by the blade from the stop rod, sends the starting handle of the loom out

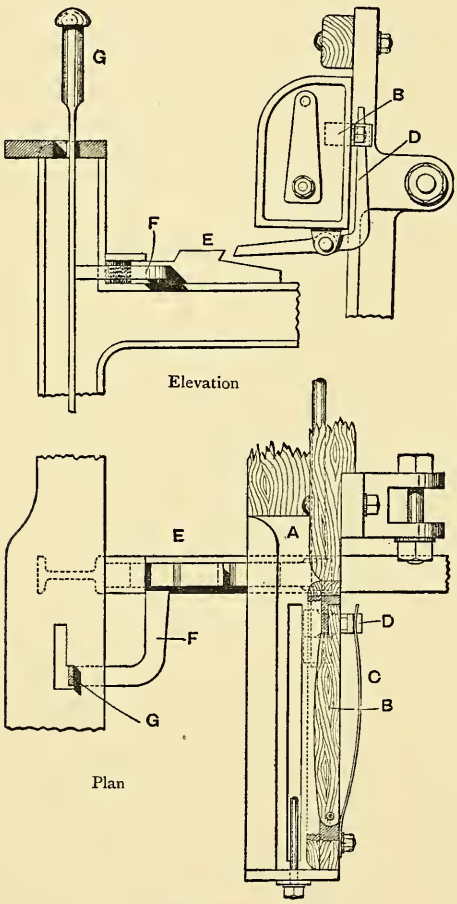


Fig. 338.—Shuttle-box Swell

A, Shuttle race. B, Swell. C, Spring. D, L-shaped lever making contact with the sliding block E attached to the arm F, which throws the starting lever G out of the notch.

of its notch, transferring the driving belt from the fast to the loose pulley, and stopping the loom. In shape and gearing shuttle swells vary largely; the qualities desired in the appliances are flexibility, certainty of action, and smoothness of working. If the spring is too strong, it is apt to cause the shuttles to rebound, and wears them out quickly; if too weak, the stop-motion is apt to act irregularly. Other swells are fitted with a braking gear, which gradually bring the loom to a standstill. The simpler the swell, however, the better, if it can be made to give an average of good work.

Shuttle Guards.—Another small mounting is the shuttle guard. Heavy shuttles flying at the rate of 30 ft. per second are apt to leap out of the race occasionally, and injure the operators, sometimes fatally. From one cause or another the point of the shuttle tilts upward and catches on the edge of the warp, to go flying in erratic whirls out from the loom; or the shuttle has been impelled from the picker at the squint, and it dives against the reed, to smash back through the warp and out to the face of the weaver. The directions which the shuttles take are incalculable and therefore difficult to guard against. An astonishing number of patents have been taken out on this subject; they vary widely, but it is possible to class the guards under four classes, viz. the wing, rigid, semi-automatic, and automatic.

Wing guards are the most primitive of these appliances, and have almost gone out of use. They consist of a pair of wire nets held firmly over the space between the breast beam and the slay when the latter is at the extreme of its backward traverse. This guard has no power to prevent the shuttle from flying out of the loom, but it catches it when it does break out. The guard has been proved to be a hindrance, however, and weavers very commonly put it aside, preferring to take risks to losing time.

Rigid guards are more generally favoured, and commonly consist of a set of brackets screwed upon the slay cap, about half the length of the shuttle apart. The foot of each bracket is bent parallel with the upper line of the warp, slightly above its highest level in shedding. These brackets cannot be brought close up to the shuttle boxes, because of the obstruction offered to change of shuttles, and the guards cannot prevent the shuttle from breaking out at both edges of the cloth.

Semi-automatic guards are constructed to move automatically into working position at the first beat of the slay. The class is very numerous, but those in use show very little originality. All seem

to ring the changes upon brackets fixed to the slay cap, with spring-controlled rods attached. Springs, rods, and brackets are variously shaped and related, but the contrivances differ in no essential feature.

Automatic guards are most desired, and the devices made and offered to manufacturers are very varied. The form generally adopted consists of a light shaft mounted behind the slay cap, upon which two arms are set-screwed, supporting flat bars which pass from back to front, between the slay swords and the ends of the reed. The light shaft is vibrated from the loom shaft, and the oscillation causes the arms and bars to keep rods over the path of the shuttle. The chief defect of this class of guard is that it must go out of action about two picks before the loom stops. It often happens that those two picks are the most likely to cause the shuttle to leap out.

The whole problem of shuttle action and shuttle guards requires thorough investigation. Experienced loom machinists assert that the difficulty comes in outside the shuttle guards altogether; the mischief, they assert, comes from faulty construction of the tappets or other picking gear. Make that right, say they, and you will do without shuttle guards.

Weft-stop Motion.—No fitter appliance for its purpose has been invented than the weft-fork stop motion employed almost universally on power looms. Improvements have been made on the original, said to have been invented by Mr. C. Gilroy, in 1831, but the principle of the action has not been altered. The simplest form of the weft-fork motion is that applied to tappet looms; it very clearly illustrates the general character of the motion (fig. 339). A cam on the low shaft of the loom works against a lever called the hammer, hooked at the upper end, and capable of catching into the end hook of a weft fork, if the latter is brought within the area of its movement. The weft fork has three prongs at one end and a hook at the other, while it is connected with what is called the *fork lever*, extending horizontally from the end of the fork to where the handle of the driving-belt fork is placed. A grid has been cut in the side of the slay fronting the shuttle race, and between the shuttle box and the reed; through the hole or grid the weft-fork front prongs will pass unless prevented by a thread of weft. So long as the weft thread remains intact, the weft fork keeps its position, and is held out of contact with the lever hammer constantly being vibrated by the cam on the low shaft. Whenever the weft breaks, however, a change suddenly

comes over the whole apparatus. The weft fork, no longer tilted up out of the way of the hammer, is caught by it, and fork, fork-holder, and fork lever are borne bodily back. The starting handle is held in place by a catch, while a spring impels it the other way. The backward movement of the fork lever sends the handle out of the detaining hook, and the spring draws it forward, imparting the lateral motion to the belt fork which lifts the belt from the fast to the loose pulley.

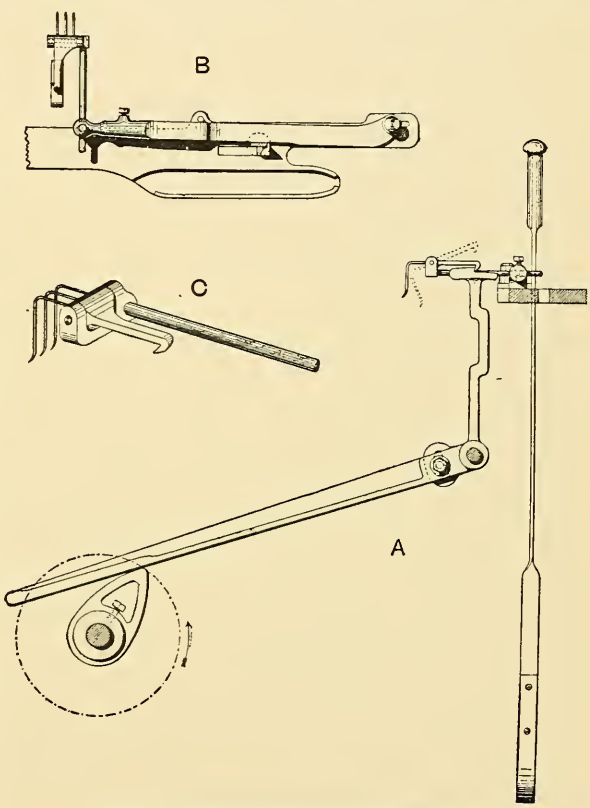


Fig. 339.—Weft-fork Stop Motion for Power Loom

A, End view. B, Part plan. C, Perspective view of weft fork, enlarged to twice the scale of A and B.

This weft fork is placed at one side of the loom, and therefore acts on alternate picks. It is therefore unsuitable for pick-at-will and very broad looms. On the latter the weft may be broken at a point remote from the fork, and the effect fail to be felt by the loom till some damage has been done. In the case of the former, a pick may be repeated from the side of the loom opposite to the weft fork, and the broken thread cause no stoppage till after two picks have been passed. For these reasons the centre weft fork has been adopted. The weft fork is fixed in the centre of the shuttle race board, and is held by the weft above the warp yarns so long as the weft is intact; when the weft breaks, the fork drops into the groove in the race, and meets the hammer with its lifted end, causing the belt fork to be thrown back and lifting the belt from the fast to the loose pulley.

Various other devices have been invented to give certainty and accuracy to the weft-fork stop motion, but the dropping of the fork

and the contact thus established between the starting handle, or belt fork, and the levers acted upon by the fork, are always the factors in the operation which matter.

Warp-stop Motions.—No warp-stop motion has been invented which has commended itself as of any practical value to the ordinary manufacturer, the chief reason being the amount of extra labour involved. All the efficient warp-stop motions are fine steel, or metal drop detectors, through which every thread of warp must be led. This means another heald and drawing operation, and it becomes a very dubious gain. For automatic looms, such as the Northrop and the Burnley, some warp detector is an imperative necessity; but the ordinary loom is generally operated without the appliance.

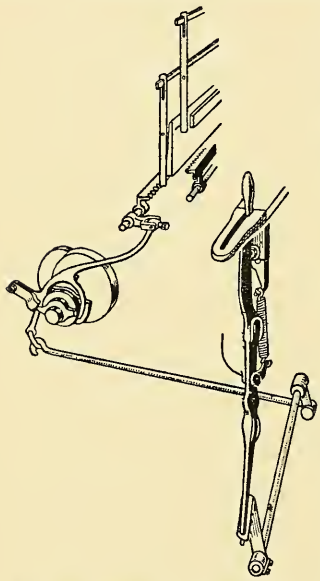


Fig. 340.—Northrop Warp-stop Motion

Northrop Warp-stop Motion.—Being the most effective of the drop detector type of warp-stop motions, the Northrop mechanism is worth examining apart from the loom itself. With that unresting changefulness characteristic of the people of the United States, the Northrop Company machinists have made many alterations and improvements upon the warp-stop motion; but the form which is generally recognized, and typical of others in use, is called the single-thread warp-stop motion (fig. 340).

Two rows of thin plates, called *detectors*, are slung on rods across the warp, in a frame carrying a serrated comb. Solid at the base, a detector is slotted to pass over the hanging rod, and a hole in the middle of the plate, under the long slot, lets the warp threads through. While the warp thread is intact, the detector plate hangs loosely upon the rod, depending wholly upon the thread; as soon as the thread breaks, the detector drops into the slot in the comb beneath it on the frame. This comb oscillates to and fro, on the arms of a shaft supporting it. Upon the shaft a pair of spring clutches catch into levers which are the arms of levers connected with the cranked levers acting, in the end, on the hook enclosing the stop handle of the loom. A cam fixed on the picking shaft imparts a rocking movement to the shaft and comb supported on the shaft, so long as the loom is going with all the warp threads intact;

but when a warp thread breaks, another action takes place. The oscillation of the comb is arrested, the stoppage bringing a set of connected levers into contact with projections on the boss of the cam, which throws the handle of the loom out of gear. Each row of detectors acts on one side of the set of levers, and both have the effect of stopping the loom almost instantly.

An Electric Stop Motion.—It is in the direction of electric appliances that the warp stop motions of the future are to be sought

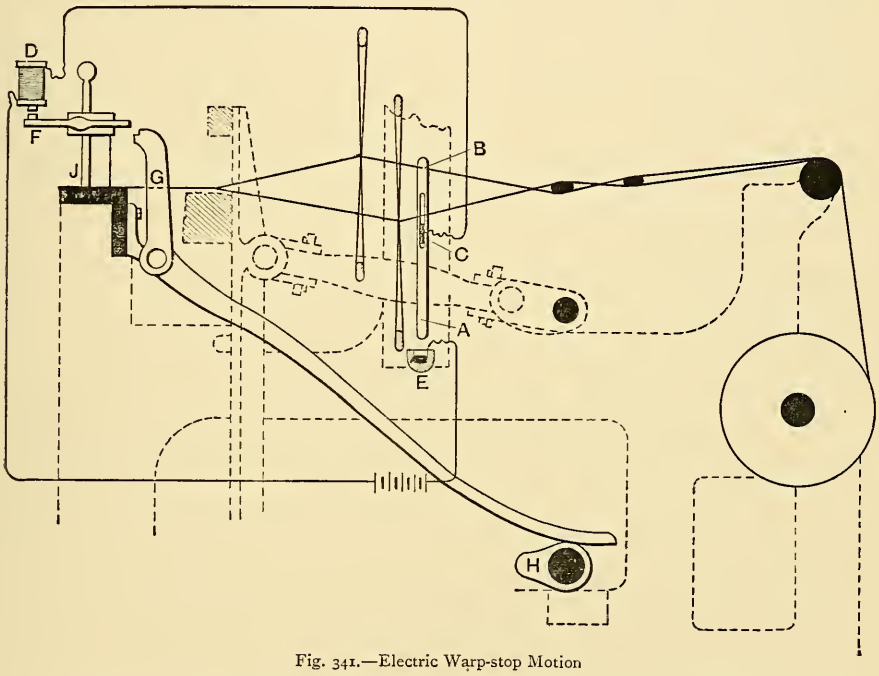


Fig. 341.—Electric Warp-stop Motion

A, The detector, a thin strip of iron drilled with a warp eye B, and slotted for the admission of a flat rod C which acts as guide, and is connected by a wire with the coil D. E is a pan of mercury into which the other wire of the electric circuit is led. When the detector falls on the breaking of a warp thread, it dips into the mercury and closes the circuit; the armature F is drawn towards the magnet, and its inner end is caught by the hammer G, which, actuated by the cam H, forces the slipper-handle J, on which the armature is pivoted, out of its notch and stops the loom.

(fig. 341). One of these at present in use is called the *Carver warp-stop motion* (fig. 342). The back and front lease rods are inserted in the warp, with ends secured in a pair of frames. In this frame an adjustable comb clamp, slotted longitudinally to take in a series of wire combs, is also fixed. A strip of metal fits into the side of the front lease rod. Against a metal bar under the warp the backs of the combs rest, the warp threads being crossed between the lease rods, and a tooth of the comb passed between them. When the warp thread

is unbroken, the comb teeth are held forward by the threads; but when a thread breaks, the comb springs into an upright position, and comes in contact with the metal bar on the lease rod. From a small electric battery, at the end of the loom, wires are connected with the plate upon which the combs rest and the metal plate on the lease rod; when the comb forms the connection between the two plates, the circuit is complete, and the electric current acts upon the lever working against the belt fork of the loom.

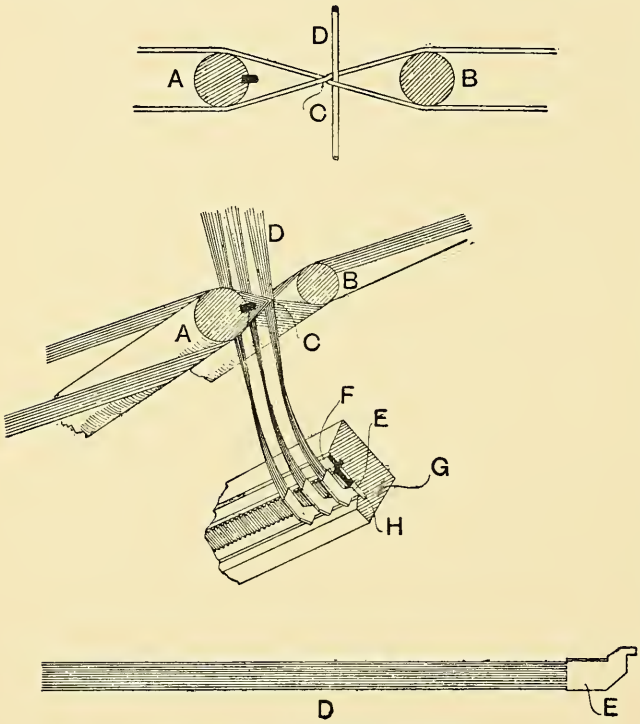


Fig. 342.—Carver's Electric Stop Motion

A B, Lease rods, of which A is furnished with a metal slip forming part of the electric circuit. C, The crossing of the weft threads. D, Wires attached in groups to shoes E, which fix into V-shaped grooves in a rack F, also forming part of the electric circuit. G, Cross-bar. H, Groove to hold projecting tongue of the shoe E. The arrangement allows of any number of wires being inserted according to the fineness of the cloth. When a thread breaks its wire D makes contact with the metal slip in A and completes the circuit.

Positive Letting-off Motions.—Management of the warp demands much care and skill, even on the simplest looms working the plainest of fabrics. After the weaver has correctly adjusted lease rods, sley, and healds, obtaining a satisfactory shed, other factors remain, which, if not brought under control, will render all his careful labour fruitless. The warp must be kept at an even tension, and yet yield to the shedding, the contraction of the threads in weaving with the weft, and the draft of the cloth. Reconciliation of those contradictions can only be approximate. Hand-loom weavers employ cunning adjustments of weight on the warp beam, to maintain the tension, to yield elastically to the draft of shedding, weaving, and the winding on of the cloth upon the cloth beam. Negative letting-off serves very well on the hand loom, and even light

fabrics, such as cottons, may be woven by power on that system, but no arrangement of weights and ropes is able to adjust itself so gradually and in such rapid sequence as the heavy power loom requires. Positive letting-off is highly necessary. The warp should be delivered, not drawn over, and delivery exactly proportioned to the amount of warp taken up by every pick. Devices for positive letting-off do little more than render automatic the old weighted rope contrivance of the hand loom, complex though many of them are. Up till the present all attempts to give a purely positive action to the letting-off appliances have failed. At one point or another the most pretentious of those motions found in actual work bring the weighted lever into service. This feature introduces an experimental factor into the motion which a perfected mechanism could dispense with. Weight is not a very efficient mechanical device, but a makeshift, uneconomical and unreliable. In view of this, the confessedly immature condition of warp-letting-off appliances, we purpose exhibiting only one of the many to be found working in the weaving sheds of this country.

On the head of the warp beam a toothed wheel is fixed; into the wheel works an endless screw, or worm, at the end of a long shaft, properly named the letting-off shaft (fig. 343). A set of pinion wheels, with fine, medium, and coarse pitch, sit on the shaft, while its farther end is balanced by a brake wheel, weighted with rope and weights. Parallel with the letting-off shaft, the letting-off lever curves down over a cam on the crank shaft of the loom, with a tongued fulcrum pinned in the back frame of the loom. From the end of the letting-off lever a connecting rod, with a catch, descends to link into the teeth of any one of the small toothed wheels on the letting-off shaft. On a knob above the fulcrum of the letting-off lever the ends of a long bolt case are pinned, the bolt holding a screw, from the end of which a long hook extends to catch into a stud on a double-armed lever, forming the side of the warp rest, lifting it up from the warp beam on to the level of the loom. In the horizontal arm of the support a rod with weighted lever is bolted, counterbalancing the pull of the hook on the letting-off lever.

At three points in this apparatus, changes in the rate of delivering the warp may be made. The weight on the horizontal arm of the warp rest checks the inward motion of the vertical arm to which the hook from the letting-off lever is attached by the stud, lessening the up-and-down traverse of the lever, and therefore the drop of the catch working in the letting-off shaft, the worm wheel on the end

of which acts on the wheel of the warp beam. The screw of the hook connecting the letting-off lever and the vertical arm before mentioned, may be shortened, reducing the length of the drop catch, and the turning of the letting-off shaft. The catch itself may be geared into any one of the three pinion wheels on the letting-off shaft, the fine, the medium, or the coarse, turning the letting-off wheel accordingly. For, when the cam on the crank shaft elevates

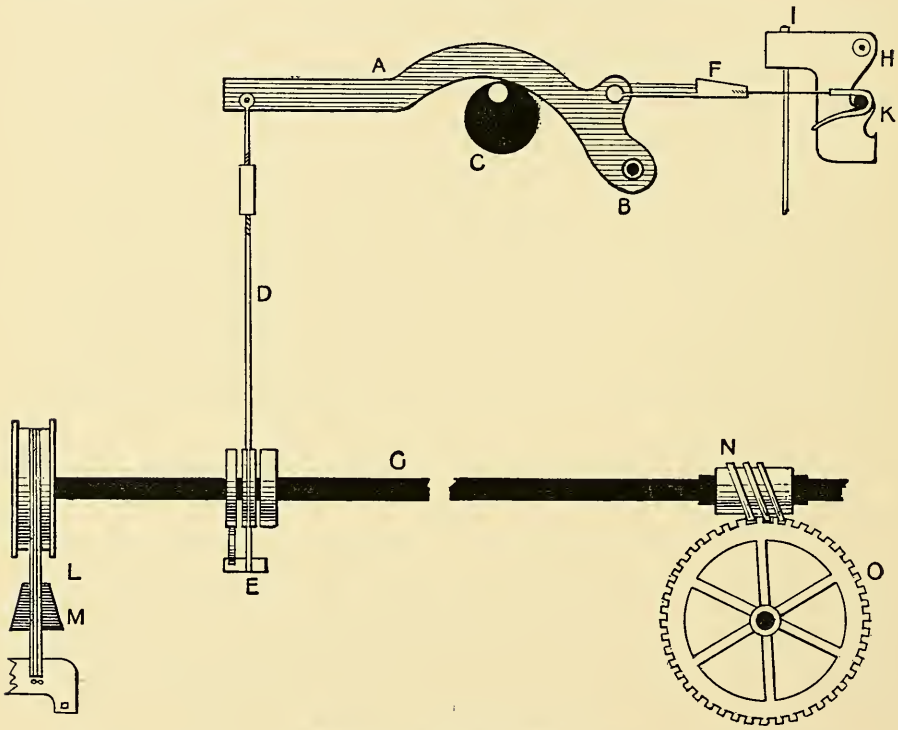


Fig. 343.—Positive Letting-off Motion

A, Lever. B, Fulcrum. C, Eccentric. D, Catch-rod. E, Catch. F, Lever checking screw. G, Main shaft. H, Pin. I, Support. K, Hook. L, Strap. M, Weight. N, Worm thread acting on wheel.

one end of the letting-off lever, the catch on the end of the connecting rod at the other end of it is dropped, but only so far as the inclination of the vertical arm of the warp-rest lever, combined with the length of the hook attached to both the latter and the lifted end of the letting-off lever, will permit. Again, the coarseness or fineness of the wheel into which the drop catch works modifies the movement of the letting-off shaft.

The warp-rest lever, however, has also an action which lends flexibility to the whole motion. Working upon a pin at its centre,

the lever allows the back roller over which the warp passes to be drawn slightly inwards by the draft of the insertion of the weft thread, the weight on the rod attached to its horizontal arm modifying its action sufficiently. But a thick thread of weft exercises greater pressure than a thin thread, and therefore causes a greater inclination inwards of the vertical arm, lengthening the up-and-down traverse of the letting-off lever and drop catch, and the whole action of the appliance. To this extent this letting-off apparatus is automatic, adjusting the giving off of the warp to the thickness of the weft threads and therefore to the length required.

Another highly important quality to be observed is the natural yield of the whole. Changes in atmosphere affect warp threads, causing them to contract and expand. With a rigid mechanism we have no means of finding an automatic adjustment to the changing conditions. It will be seen, however, that this mechanism changes by itself, and may be also delicately re-adjusted if necessary.

We have the patents of Wilby, Hutchinson & Hollingworth, Keighley, Northrop, and others, all possessing merits of their own. Closely analysed, however, all the letting-off motions are combinations of weights, levers, worm wheels, and graduations of cam and spring, more or less to be identified with the motions already examined. One of these motions thoroughly understood enables a worker to comprehend all with a very little trouble.

Setting-up Motions.—Winding the cloth on the beam is the last act of the loom. If it were possible simply to weave the cloth, and afterwards wind it up at leisure, some trouble would be saved, in weaving at least. A certain latitude is permitted the hand-loom weaver in this respect. He may, if he chooses, refuse a mechanical cloth-winding motion, and draw the cloth round his beam at intervals the duration of which he determines for himself. We have seen a long-armed weaver winding on three or more inches on the cloth beam at one time. Latter-day practice, however, is as remote from that easy-going method as possible. Even the hand looms are equipped with mechanical setting-up motions. Like the letting-off motions, the setting-up appliances are classed as negative and positive. The latter are preferred by weavers of light fabrics, and the former are preferred by the weavers of woollens, worsteds, and other kinds of heavy fabrics. At bottom, the principles of both are identical, but the application of the principles certainly differs very widely.

Positive Setting-up Motions.—Automatic efficiency is the aim of

the inventors of positive taking-up motion. Their object is to make the loom independent of the intelligence of the weaver. Practical experience does not show that any positive motion yet invented has fulfilled the ideal; but most of the appliances work well enough under skilled and careful supervision.

Intermittent Positive Motion.—Positive motions are either intermittent or continuous, acting, according to adjustment, either when the slay is going forward or when it is coming backward. The cloth beam is turned by friction with a roller covered with a thin fillet of steel roughened like a file. This *sand or friction roller*, as it is called, draws the cloth from the reed, and causes it to wind round the cloth beam, hung in gudgeons upheld by weighted levers, which press it firmly against the sand roller. Placed so that its axis is parallel with the harness, the friction beam has its bearings in the end framing of the loom. Upon the end of the beam farthest from the driving gear a toothed wheel is set-screwed upon the shaft, the teeth of the wheel engaging with a stud pinion compounded with a stud wheel. The stud of both the pinion and the wheel is adjustable and bolted to a slotted bracket, the slot being concentric with the friction beam. The pinion is the driver of the friction beam; we have to seek further for the power which drives it. The wheel with which it is compounded drives the pinion, or, rather, transmits power to it. At the toothed edge of the wheel we find a pinion the teeth of which engage with the wheel teeth; compounded with this pinion, and forming what may be called its base, is a circular ratchet. Whatever acts upon the ratchet is evidently the driving force of the setting-up motion. From its fulcrum pin in the loom frame a lever, slotted at the end and carrying a loose pawl near the head, works upon an adjustable stud on the slay sword. The pawl point rests in the teeth of the ratchet. As the slay sword moves forward, the stud slides along the slot of the lever, drawing the pawl back and causing the ratchet to turn; the pinion compounded with the ratchet turns with it, and acts upon the stud wheel and pinion compounded upon it, the latter conveying the motion to the friction beam which draws forward and winds on the cloth (fig. 344)

To keep the ratchet steady at the point where the pawl has left it, another pawl is attached to the other side. This pawl is pinned to the end of a rod extending across the loom, from which a finger projects into touch with the weft-fork lever. When a weft thread breaks, the pawl is lifted and the setting-up motion arrested.

Other forms of the same contrivance are in use. Some have the holding-up catch fixed in the plate of the wheel of the friction roller; others turn the lever upside down, letting the slay sword act as it moves backwards; others again adopt a different shape of slotted lever; some make a longer train of wheels; none, however, alter the motion essentially.

These and numerous alterations have been inspired by two opposite reasons. On the one hand, the motion is handy, light and simple, easy to understand, and practically automatic. On the other hand, it is distinctly weak in two points. The friction roller is not certain in its action, and we have no means of controlling it. More important is the other weak point, viz. the pawl. For the purpose, the pawl must be loose, easily lifted, and readily dropped; if, from the vibration of the loom or any other cause, the pawl misses a tooth of the ratchet, correction is impossible.

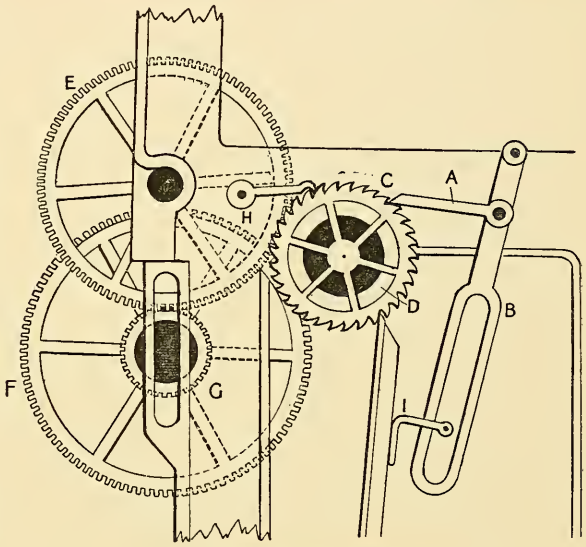


Fig. 344.—Change-wheel Setting-up Motion

A, Driving pawl. B, Lever. C, Ratchet wheel. D, Change wheel. E, Cloth beam wheel. F, Intermediate. G, Pinion. H, Holding-up pawl. I, Spring catch.

Change Pinions or Change Wheels.—Wefts vary in thickness, and cloths vary in the number of weft picks they contain per inch. The setting-up motion must also vary in accordance with the differences in those factors. Alteration of the rate of setting-up requires that either a driving or a driven wheel be found in the train which can be changed. To increase the rate a driving wheel is enlarged, or the number of teeth on it increased, and for the same purpose the driven wheel is reduced in size, or the number of its teeth decreased. We may plan to change either a driving or a driven wheel, but the practice most common is to make the pinion of the ratchet, which is a driver, the change wheel. Having determined how many picks per inch are to be in the cloth, we assemble the known driven

wheels together, and the known drivers, together with the circumference of the friction roller and the number of picks desired, multiply each set of factors together, and then divide the former by the latter. The result will tell the number of teeth required on the change pinion.

Example: Suppose we want a change pinion which will give 64 picks per inch, with a friction beam wheel of 75 teeth, a stud wheel of 100, a ratchet of 50 teeth, with a stud pinion of 12 teeth, and a friction beam 15 inches in circumference. Then: $75 \times 100 \times 50 \div (12 \times 15 \times 64) = 32.55 = 33$ teeth on the change pinion.

In practice the problem is seldom so extensive. We are generally required to find what number of teeth should be on one change wheel in comparison with the change pinion already on the loom. Suppose, therefore, we have woven the cloth of 64 picks per inch, and now have to weave a cloth with 80 picks to the inch. The friction beam must in that case be driven more slowly. We therefore reduce the number of teeth on the change pinion. To find how many less, we multiply the number of teeth on the change pinion at present in use by the number of picks it produced, and divide by the number of picks to be next inserted. Thus: $64 \times 33 \div 80 = 26$, the number of teeth required.

Continuous Positive Setting-up Motion.—When continuous positive setting-up is adopted, no change as a rule is made on the train of wheels, but instead of a ratchet and pawls attached to the slay sword, a shaft is driven at right angles from the picking shaft through a pair of bevel wheels, and a worm is fixed on the shaft, to gear into the toothed wheel carrying the change pinion in the same position as the ratchet. Driven by the constant revolution of the picking shaft, the worm continuously turns the toothed wheel with which the change pinion is compounded, the latter driving the train of wheels as before. For one thing, the continuous positive motion eliminates the chance work of the pawl, imparting certainty to that part of the mechanism. It is rather remarkable, however, that the motion has not displaced the intermittent appliance to any great extent. A great many workers, otherwise well-informed, have no knowledge of the continuous motion.

Negative or Lever-and-catch Setting-up Motions.—As we have already hinted, the form of negative setting-up motion most commonly employed in woollen, worsted, and other heavy fabrics is nothing more than the hand loom taking-up motion made mechanical by

attachment to the slay sword (fig. 345). A rod from the slay sword is attached to the end of a lever, the one extremity of which is weighted, while on the other end a pawl is pinned loosely, the pawl gearing into the teeth of a catch wheel, on the boss of which is a pinion acting upon the wheel of the cloth or piece beam. The action of the rod from the slay sword is governed by the weights on the end of the lever, the heavier the weights the more quickly the pawl moves round the catch wheel, winding the cloth on the beam. A double pawl set above the catch wheel modifies its revolutions, being set in such a way as to restrict the effect of the main pawl. Some weavers prefer to drive the lever from the loom crank shaft, by means of a cam; but the revolution of the crank shaft and the movement of the slay sword being practically identical, the change makes little difference in working.

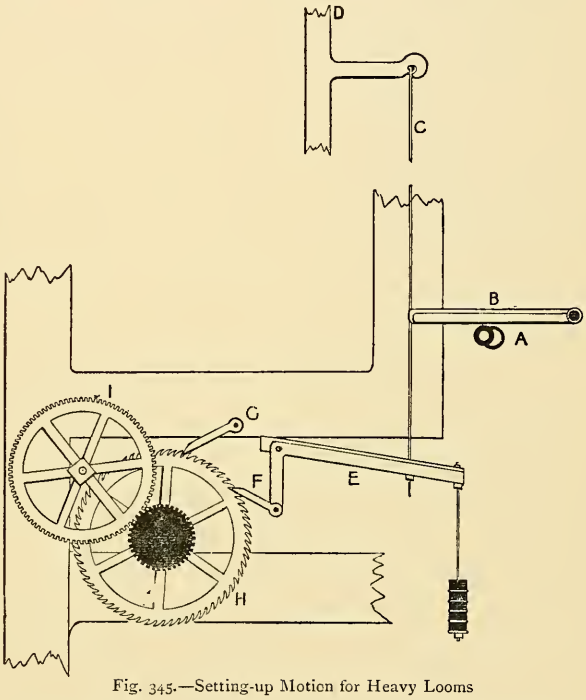


Fig. 345.—Setting-up Motion for Heavy Looms

A, Crank shaft with eccentric. B, Setting-up lever driven off crank shaft. C, Connecting rod. D, Sword. E, Setting-up lever. F, Setting-up catch. G, Holding-up catch. H, Ratchet wheel. I, Beam wheel.

Setting-up Motion for Plush Looms.—Positive setting-up motions are frequently used by weavers of plushes, velvets, and carpets, but the negative motion has some features which commend it for that class of fabrics. One of the most useful is the following. On the end of the cloth roller a worm wheel is fixed, and a worm from a short shaft gears with it. The shaft carries two ratchet wheels, the one being the driver and the other having three holding catches all of different lengths. The short shaft also forms a fulcrum for a slotted lever, carrying the pulling catch. At the end of the slot in the lever hangs a weighted stalk, with a collar near its lower end resting upon a slotted lever coming out from the slay sword. When the slay sword

begins to move to and fro, it lifts the stalk with its weights, through the medium of the slotted lever. The stalk elevates the slotted lever carrying the pawl acting upon the ratchet wheel. As the fabric slackens, the weights drag down and cause the pawl to pull round the ratchet wheel into which it has already been geared by the lifting motion. The holding-on catches on both ratchet wheels then prevent any backward motion. The turning of the ratchet wheel, as we have noted, causes the worm to turn in the worm wheel on the end of the cloth beam, and winds on the cloth.

Temples.—A thread tightly drawn across another set of threads, like a weft thread upon warp, naturally tends to contract the width of the crossed threads. For a moment the reed holds the warp threads at the proper width, but when it retreats, the cloth would be free to contract if some other agent were not called in to prevent it. The agent constantly employed has been called the *temples*, from the old word template, a stretcher. Upon the hand loom the temples still used are actual wooden stretchers furnished with pins on the ends to catch into the edges of the cloth, the two pieces of flat wood dovetailing into each other, at whatever angle the width of the cloth may require. For the power loom, however, some form of automatic temples was required, though the need was not very generally admitted till late in the nineteenth century, the majority of manufacturers being content to rely upon the old wooden temples, even for fast looms. Inventors, however, have been busy from the time when Dr. Cartwright, in 1786, patented a kind of automatic temple, right up till the present date. The variety of temples now in use comprehends many types, the chief of which are the *trough-and-roller*, *single-roller*, *double-and-triple roller*, *inclined- and horizontal-ring temples*. The chief problem which the inventor of self-acting temples has to solve is to combine gentleness of hold with firmness, flexibility with security. Thin goods may be marked with the teeth of temples which do not adequately grip on heavy goods. Though not one temple can be described as perfect, most of those employed perform their functions with approximate efficiency.

Trough-and-roller Temples.—Invented by Messrs. Kenworthy & Bullough in 1841, the trough-and-roller temple serves very well for light fabrics (fig. 346). Supported on two long springs bolted to the front rail of the loom, a semicircular iron trough is placed beneath the cloth, within a short distance of the extreme end of the reed traverse. Over the cloth, and pressing it down into the trough, is

a long roller, held down at both ends by caps. The roller is plain at the centre for about 4 in., with corrugated flutes forming right-handed threads at the one side and left-handed flutes at the other, making a series of teeth to grip into and spread the cloth, which is also held by the roller against the edges of the trough. The grip of the roller is uniform, but very light, and can hardly be considered sufficient for any but the lightest of cloths.

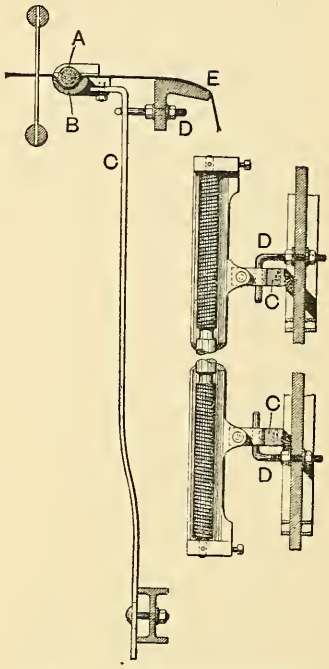


Fig. 346.—Trough and Roller Temple

A, Roller. B, Trough. C, Springs supporting the temple. D, Adjustable hooks to regulate its position. E, Breast beam.

Roller Temples.—In principle all roller temples are very much alike, differing chiefly in the number of rollers and the shapes or dispositions of the spikes and corrugations (figs. 347–8). The main idea consists in having spiked rollers, inclined towards the outside, flexibly fixed at both sides of the cloth, with cases or caps, which, while allowing the cloth to pass through, hold it down to the centres of the rollers, so that the spikes may retain a firm hold. The fixings permit of lateral adjustment, and for moving the appliances forward or backward. Springs of various shapes hold the temples forward, and yield easily to the stroke of a shuttle or reed.

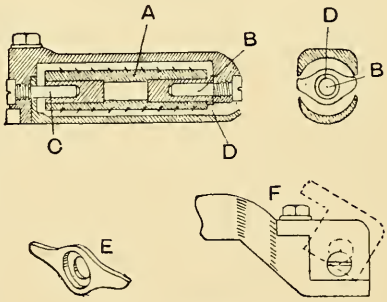


Fig. 347.—Dutcher Temple

A, Temple roll revolving on studs B C. The bush in which stud B works is extended at D, where it is passed through a dust-excluding protector E. The manner of closing roll is shown at F.

Choice of Temples.—Ring temples, horizontal and inclined, temples which stretch as well as hold the fabric, and all the various shapes, surpass in variation the space available for clear and detailed examination. Professor Fox, whose experience entitles him to speak with authority, says: "Other things being equal, the best temple is that which will grip and stretch a cloth nearest to the fell; stretching a piece half an inch or more from that point is less efficient. The Dutcher temple enables cloth to be stretched nearer the fell than most others (fig. 348). Its case has a shank cast upon it

which is partly oblong, partly cylindrical. Upon the cylindrical portion an open coiled spiral spring is loosely threaded; one end impinges upon the oblong shoulder, the other upon the end of a slotted box in which the shank is placed, the box being adjustably secured upon the breast beam. As a slay recedes from the fell, the spring pushes the temple forward. By this means a temple case can be set in advance of the fell, without risk of injury to the reed. In practice it has been found

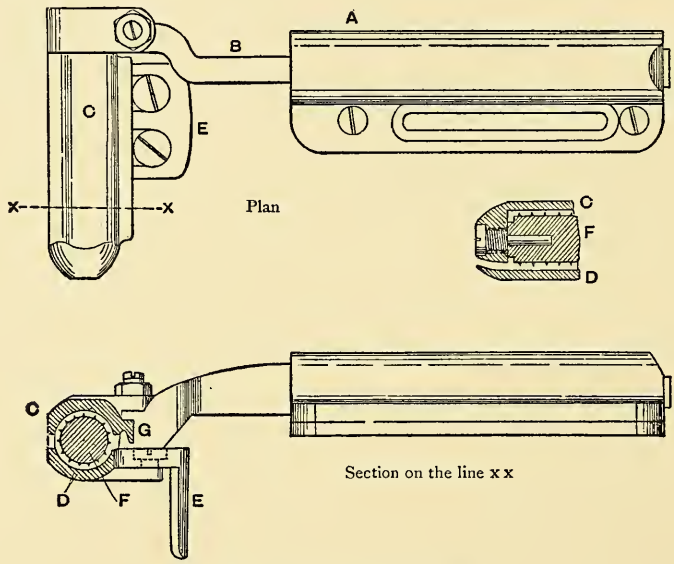


Fig. 348.—Improved Dutcher Temple

A, Bracket. B, Shank. C, Cap. D, Pod. E, Heel. F, Roll. G, Guard to prevent injury to the teeth.

that thin goods are marked by temple teeth, and stout goods are not properly held. In this roller the teeth are longest near the outer end and taper down to the inner end. For fine goods they are uniformly distributed over the roller, as then they do not pierce the cloth, but release it freely. For stout cloth half the pins are removed from six outside rows, in order that those remaining may more readily pierce the cloth and hold it longer. The roller is made of wood; it is $2\frac{1}{2}$ in. long by $\frac{9}{16}$ in. diameter, and is bored axially to receive and turn freely upon stud journals. Each stud has a thread cut near its head, but the remaining portion is smooth. The temple cap is tapped at each end to receive the studs, but the smooth portions enter the roller. In order to make one bearing dustproof, the inner end of a roller is turned down to fit inside a recessed cap."

Selvages.—To prevent fraying at the edges, twills, cords, and

plush fabrics are edged with a list or selvage, woven in a pattern different from the body of the cloth. Side selvages are comparatively easy to manage, but centre selvages between two breadths of cloth woven at the same time have puzzled the ingenuities of loom mechanics. Evasion of the pattern order of weaving, without incurring the loss of a pick, is the twofold problem. By observing the methods by which the difficulty has been met in side selvages, we may be assisted to understand more readily the centre-selvage appliances.

Methods of Making Plain Side Selvages.—A simple machine for weaving plain side selvages consists of two groups of healds on each side of the web, behind the ordinary heald shafts, hung over pulleys on a shaft fixed horizontally across the loom, at about the level of the tops of the loom frame. On one side of the pulley a cord descends, to be looped into the wires carrying the set of healds into which, say, all the even-numbered warp threads have been threaded; on the other side of the pulley another cord holds up the healds carrying all the odd-numbered threads of the selvage warp. The pulley at the opposite side of the web does the same service. Cords are fastened to the ends of each group of healds, the one group being attached to a light lever, acted upon by a cam on the low shaft of the loom, and the opposite group being attached to a coiled spring, light enough for the lever to extend it. Suppose the structure has been placed in position, and examine how it operates. The cam lifts the lever, and lets the spring opposed to it draw the healds attached to that side down, while the healds attached to the lever rise. At the passing of the cam the lever falls, drawing down the healds connected to it, and drawing up the healds on the opposite side of the pulley, by extending the spring. Scarcely any difficulty occurs with this device, though it may not meet every case.

Boat Selvage Appliance.—Shaped like a piece of roller beading, rather than a boat, the wooden body is about 2 in. long, the roller running the long way on its upper surface, the under surface being flat. Preparing this so-called boat, the weaver makes a hole through the centre of the projecting roller, and fixes a pair of leather ears to the sides. A series of reed wires are twisted together at one end and riveted on to the top of a leather piece; the other leather piece is similarly equipped; then both sets of wires are bent over. A pair of these boats are made, one for each side of the web. Pins bolted to the loom frame are run through the hole in the centre of each boat, to support them. Placed a little way behind the healds,

below the warp line, the boats are threaded with the selvage warp. Alternate threads of warp are passed through each set of wires on the sides of the boat and then through the mails of the heald shafts in front. Both boats are equally treated. When a heald shaft lifts the even-number threads, that side of the boat the wires of which contain those threads is lifted up, tilting over to the side, depressing the other threads, and opening a shed. As a rule the selvage can thus be woven plain, but in all cases a modification of the pattern on the web can be obtained.

Centre Selvages.—Sometimes two pieces are woven in the width of the loom. Between the two fabrics selvages are formed by plain, gauze, or twist weaving. Probably the oldest, and certainly the simplest and cheapest, of centre-selvage-forming appliances is a doup of heald twine, tied to the front shaft, and terminating in a pendent ring. First the crossing thread is passed through an eye in the back shaft, crossed under the straight threads, drawn through the pendent ring, and then passed with the straight threads into a dent in the reed. At every pick the crossed thread sustains a double lift, one to form the open shed and one to cross, the former lift being effected by the back heald shaft, and the latter, of course, by the doup heald.

Selvage Split Motion.—One of the most useful of the split selvage motions is an adaptation of the spring-and-tappet appliance used in forming side selvages, formerly described. Having two selvages to form, the appliance is double in some of its parts. A wire is bolted to a frame secured to a cross rail above the warp, the wire terminating in two coiled eyes below the warp-shed line. The wire projects outward from the frame, and a little way beneath the joining of the wire to the frame a pair of small pulleys are fixed. Round these pulleys leather straps pass, the straps having eyelets in them; one end of each strap is attached to an elastic band held by a hook at the end of the framing, and the other end is secured to a roller, or lever, actuated by the tappet, or Jacquard, or other shedding appliance. Eyelets are made in the frame itself, on the level of the warp shed. Through the latter the stationary threads of the selvage are passed. The crossing threads pass through the eyelets in the straps, and through the eyes in the projecting wire coming down below the level of the warp shed. When the straps are drawn upwards, the crossing threads are lifted, and when the straps return, the crossing threads have passed round the stationary threads, forming, with the pick of weft, a strong double line of selvage.

Other Selvage Appliances.—Spiral-twist selvages, plain-cloth, and woven selvages have been devised, and many varieties of apparatus are operating them. Most of these, however, are so costly and complex that the great mass of the operatives in the weaving industry never see them. When they are used in special circumstances, the work is undertaken by specialists, or those specially instructed.

CHAPTER X

The Going Part

The "Going Part". — Many power looms are overloaded with mountings. Shedding, picking, weft- and warp-stop detectors, selvage makers, and many other complex gearings have transformed the simple loom into a highly complex machine. Then there is such a wide variety of looms; special looms for plain, light, heavy, fancy, figuring, plush, velvet, double-cloth, and carpet weaving; the looms of the cotton, silk, woollen, worsted, linen, canvas, jute, and ramie industries. And yet, underneath all, essential to all, is the simple loom structure. Nothing illustrates this more clearly than the section of the loom described as the "going part". In every loom the frame of that structure is the same, no matter how it may be overlaid by mountings; the principles upon which it is operated are unchanged, whether the loom be the largest carpet-weaving machine in existence or the smallest ribbon loom.

The basis of the going part, in the power looms now built, is a rocking shaft, resting in bearings bolted to the side frames and extending across the loom. The chief function of the rocking shaft is to carry a pair of slay swords, or arms, one at each extremity, supporting the whole of the batten or slay, including shuttle boxes, shuttle race, or slay sole, reed, and slay cap. Upon the heads of the slay swords strong ears are cast, into which are pinned the arms which connect the slay with the driving crank shaft in the middle of the loom. The arms may be of one piece, or formed of two pieces jointed, the object being to lessen the strain upon the slay swords. The shaft into which the arms from the swords fit is cranked at the points of conjunction, to give that radius of movement necessary for the to-and-fro motion of the slay. Every slay has a certain length of

traverse, swinging from the cloth fell on the one hand to the farthest point in the shed of the warp on the other. Without this we could have no shedding of the warp, no picking of the weft, no beating up of the weft into warp, to form cloth—in a word, no weaving. The relations of crank shaft and slay, therefore, are of vital importance to the work of the loom (fig. 349).

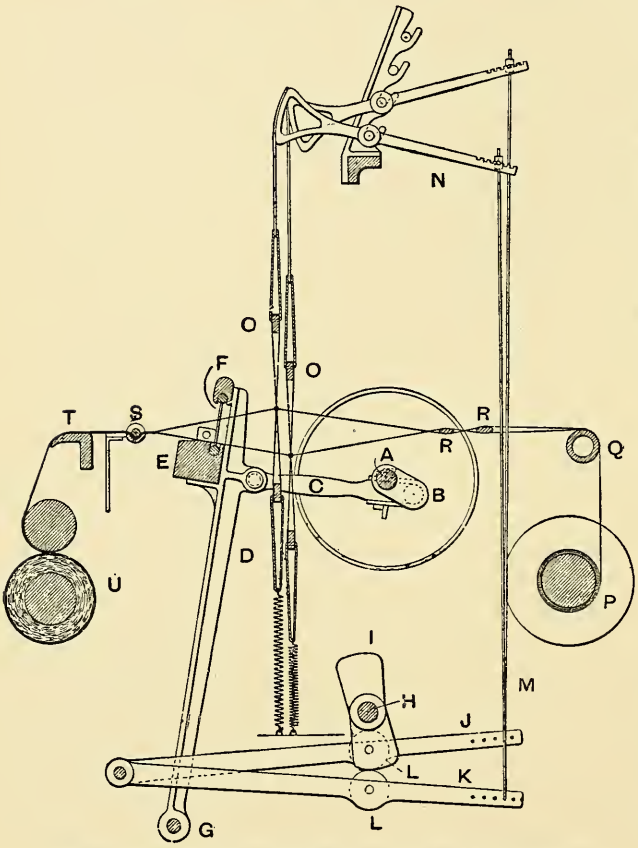


Fig. 349.—Diagram of Loom, showing Going Part and Tappet Motion

A, Driving shaft. B, Crank. C, Connecting rod. D, Sword. E, Slay sole. F, Reed. G, Rocking shaft. H, Tappet shaft. I, Tappet. J, K, Treadles. L L, Bowls. M, Treadle cords. N, Jacks. O O, Healds. P, Warp beam. Q, Back roller. R R, Lease rods. S, Temple. T, Breast beam. U, Cloth beam.

Before going farther, it is necessary to state that there are two methods of driving the loom, the one direct and the other indirect. In the direct method a pulley connects the crank shaft of the loom with the mill power shaft, and to make the crank shaft the medium of power for all the motions of the loom, including picking, shedding, taking up and letting off, and all the various mechanisms operating on every kind of loom. The other is the method preferred by weavers of heavy fabrics. A short stout shaft is placed at right angles to the crank, the connection being made with a pair of bevel wheels, one of which is a change wheel. Indirect driving gear consists of a pulley on the end of the short shaft, a bevel change wheel on its other end, gearing into a bevel wheel on the low shaft of the loom. On the low shaft a toothed wheel gears with another toothed wheel on the crank shaft, and drives it. The indirect method

of driving gives unity to the whole working of the loom, and facilitates alterations in speeds through the change wheel, thus obviating the

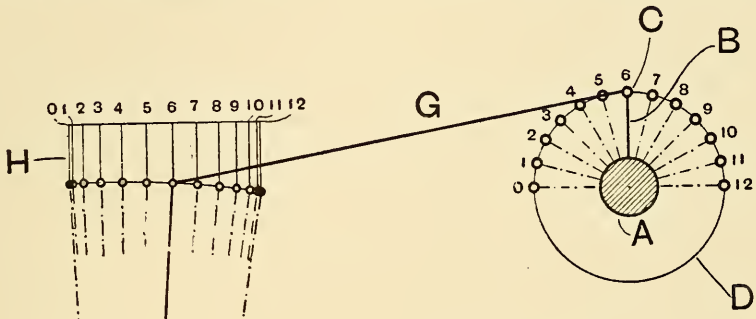


Fig. 350.—Diagram of Movements of Crank and Slay

A represents the crank shaft, B the crank, C the centre of the crank pin, and D the circle described by it. E is the centre line of the sword, F its fulcrum, and G the connecting rod. The varying spaces on the line H indicate the varying distances traversed by the head of the sword in the same space of time at different parts of the stroke.

necessity of always meddling with the driving pulley whenever a change in speed has to be made.

Relations of Crank Shaft and Slay.—Whether the method of driving be direct or indirect, it does not alter the important relations of crank shaft and slay. As the slay sword is a lever moving upon a fixed fulcrum, and the crank a bend upon a revolving shaft, both might be treated as circles, and compared on that basis, but for the fact that the connecting arm intervenes, converting the rotary motion of the crank into reciprocating curvilinear motion. Another objection to the comparison of circles, though slight, is the fact that the slay sword may not pass and repass the centre of its base, the rocking shaft.

As it happens, we do not require a regular speed of slay all through its movements; on the contrary, the apparent limitation serves the purpose of the weaver. He desires as long a period as possible for the passing of the shuttle through the warp and as quick

movement as can be attained at the extremes. In order to see clearly how this comes, let us draw a diagram representing the relative motions of crank and arm of the going part. Describe a circle representing the revolution of the crank itself. Draw a straight line through the centre of the circle and produce it to the length of the connecting arm of the going part. This will represent the actual positions of both when the crank is nearest to the cloth fell. Divide the whole circle into 12 equal divisions, and between the points of the radiating lines and the produced line of the arm draw lines the length of the arm. The distance from the front line of the circle and the converging points will lessen from 1 to 6 and increase again from 6 to 12. Nor is this all; an inequality in the distances between the points at which the lines touch is very apparent. The difference gradually increases from points 1 to 3 and decreases from 3 to 6, increasing again from 6 to 9 and decreasing from 9 to 12. What does this mean? As the crank always moves at the same speed in every point of its revolution, the arm must be moved at different speeds in the same time, traversing a greater distance. When the crank is at the top or bottom of the circle of its revolution, it imparts to the arm a greater speed than when in the middle and level with the fulcrum of the arm.

Before going on to consider the facilities which these facts afford the weaver, let us take another view of the matter. Describe a circle to represent the revolution of the crank; describe the horizontal diameter of the circle, and continue the line out to the full length of the arm of the slay. Divide this line into equal parts along its length, and draw straight lines from all the points to touch the edge of the circle at whatever point the length of the arm will permit. Having done this, you will find that the circumference of the circle is divided up into unequal parts. That is to say, it takes longer to carry the arm through one space of its movement than another. In this case the proportions of the spaces on the circle are reversed; those on a horizontal level at front and back are wide, and the spaces narrow toward the top of the crank's revolution.

Alternatively, we can view the action in its practical effect (fig. 350). According to the structure of the loom, when the crank is turned towards the loom the slay and reed are against the cloth fell; the slow approach gives the weft time to be fully extended across the warp; the slow return enables the shed to form, the shuttle to begin its course. At the extreme of the traverse of the slay the motion

is, if anything, rather slower. When on its back centre, the crank causes the arm to go slowly. As this happens at the moment when the shuttle is in full career across the shed, the slow movement affords time for the shuttle to perform the whole traverse of the web. The intermediate moments have no occupation, and therefore the quicker the crank can carry the arms through them the better.

Having established an approximate ratio of variation, the loom inventor has gone further. The shorter the arm the smaller the space upon which the variation described takes place, and therefore the greater relative difference between speed of slay at one point and at another. Or, if the crank is enlarged, the same effect results; the ratios between the length of the arm and the circle of crank revolution are changed.

A number of questions occur in this connection. For example: What is the correct ratio between the length of the arm and the circle of the crank? At what height in the sword should the pin of the arm be placed? What length should be the stroke of the slay? Upon these points no hard-and-fast rules can be laid down; width of loom, size of shuttle, make of fabric, and other minor details all enter into each problem, and variation is practically incalculable. For very fast and narrow looms the stroke of the slay should be short, the fulcrum on the arm of the sword in as nearly as possible a horizontal plane with the loom crank, and the throw of the crank as small as may be practicable. Very wide and heavy looms require that the stroke of the slay shall be long; to increase it by lengthening the arm and lowering the fulcrum point of the arm on the sword would impose a strain upon the sword greater than it may be able to stand; therefore the crank must be enlarged and its throw increased in circumference. This, as we have indicated, has also the advantage of accentuating the eccentricity of the movements of the slay.

The Whole Power Loom.—The frame of the power loom consists of two sides, or ends, based on strong sole plates, the whole structure shaped to afford solid support to the bearings of cloth beam, warp beam, and driving shafts, the connecting cross rails disposed so as to brace firmly into unity the ends or sides, and at the same time serve as fulcra for the various levers working longitudinally in the loom.

Looking at the loom from front to back, the main parts lie in parallel relation to each other thus: 1, *cloth beam*; 2, *breast beam*; 3, *temples*; 4, *going part*, carrying *shuttles*, *shuttle boxes*, *shuttle*

race, *picking arms* and *pickers*, in the case of under-motion, and *reed*, fast or loose; 5, *shedding appliances*, *healds*, or *harness*; 6, *lease rods*; 7, *back rest of warp*; 8, *warp beam*. Over-motion picking appliances, with picking arms, shafts, and straps, are independent of the going part.

Crank shaft and low shaft, sometimes called the *picking shaft*, between them bear the whole burden of driving the loom; in many weaving sheds the whole driving power rests upon the crank shaft singly and alone. Upon one end of this shaft a fast and a loose pulley are fixed, a belt connecting the shaft with the main shaft of the weaving shed.

Timing of the Motions of the Loom.—When the crank is on its fore centre, the reed is against the cloth fell, the going part is at the farthest point of its forward movement, and picking tappets, heald tappets, or harness mechanisms are all at the lowest points of their activities. As the crank shaft moves towards its bottom centre, the slay and reed begin to move out, the picking tappet turns towards its cone, tightening up the straps of the picker, while the shedding mechanisms open the shed. At the moment the crank has reached bottom centre, picking action begins, the picking arm, however actuated, giving the picker its sharp stroke; the shedding appliances, tappets, dobby, or Jacquard are in full play; the slay being in the middle of its backward swing. The crank then reaches back centre, and the shed is held wide open; the slay is at the farthest limit of backward traverse; the picking arm returns to rest. Revolving still, the crank attains top centre; the picking appliances are out of action; the shedding appliances close the shed; the slay runs smartly forward, then with slower movement beats up against the cloth fell, driving the weft; the whole loom has performed its work.

CHAPTER XI

Automatic Weaving

Automatic Weaving.—To the average mind the chief charm of the fairy tale and magic story lies in the easy attainment of wealth and happiness through the agency of some supernatural power. Fairy godmother, familiar spirit, genii obedient to ring, lamp, or spell, make grandeur out of nothing, transform poverty into riches at the

touch of a wand, a word of command. Having in mind the startling maturity of selectiveness shown in the textile fibres utilized for unknown generations, we are sometimes tempted to imagine that the present race of mankind has inherited from a former race, whose civilization was superior to ours, some fragments of the arts and crafts, and that those magic and fairy tales were merely exaggerated reminiscences of the powers possessed by the vanished race. The commoner, and perhaps more probable, explanation of those wondrous fables is that they are the dreams of a spirit touched by the sense of the infinite, the images of things hoped for, of desires yet to be gratified. Whatever they are, these ideals undoubtedly represent a strongly felt ambition. In every productive industry to which machinery has been applied effort towards bringing all the machines to perfect self-action has been constant and persistent. Nowhere has the endeavour been more evident than in all branches of the textile industry. In the spinning and preparing departments some marvellous results have been attained, but in the weaving department effort is more conspicuous than achievement. As it stands at present, the most efficient and most wonderful of looms is nothing more than a mass of complex mechanical parts, displaying fine ingenuity, but lacking in that automatic quality which accomplishes great results by simple means.

Northrop Loom. — The main obstacle to a perfectly automatic loom is the separation of the picking from the shedding actions, and the independence of the shuttle. This single tool demands attention wholly for itself. Up till lately, when a weft thread broke in any kind of loom, or when the weft spool ran out, the shuttle had to be lifted out by hand, the spool renewed, and the weft connected. The large supply of shuttles which a revolving shuttle box can carry has certainly minimized the labour of shuttle-changing; but until the Northrop loom (see Plate) appeared on the other side of the Atlantic, no means of automatically repairing the break of a weft had been accepted as practicable on the ordinary loom. The leading feature and merit of the Northrop loom is the mechanism for automatic weft supply. It embodies two actions formerly attempted by inventors in this country with some degree of success, viz. the automatic weft feeler and the ejection of a spent and the insertion of a full weft cop.

Invented in 1894 by Mr. J. H. Northrop, U.S.A., the cop-weft changer consists of several appliances, mutually acting and co-operating. First, a rotating hopper holding the weft cops; second, a

special form of shuttle; third, a set of feelers and weft-cutting appliances; fourth, a weft fork—all with requisite connections (fig. 351).

Weft Cop Hopper.—Situated on the breast of the loom, on the side farther from the driving gear, the spool hopper or carrier consists of two metal discs, sleeved on the supporting bracket, the length of the spool apart. On the inside face of one of the discs semicircular recesses are formed, based on spiral springs, to hold the heads of the spools or pirns, while the other disc grips the tips in

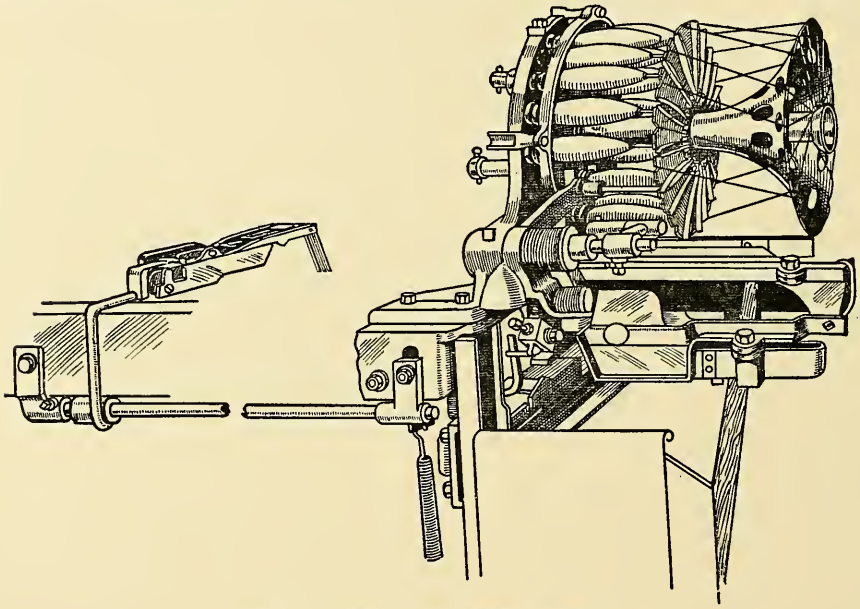
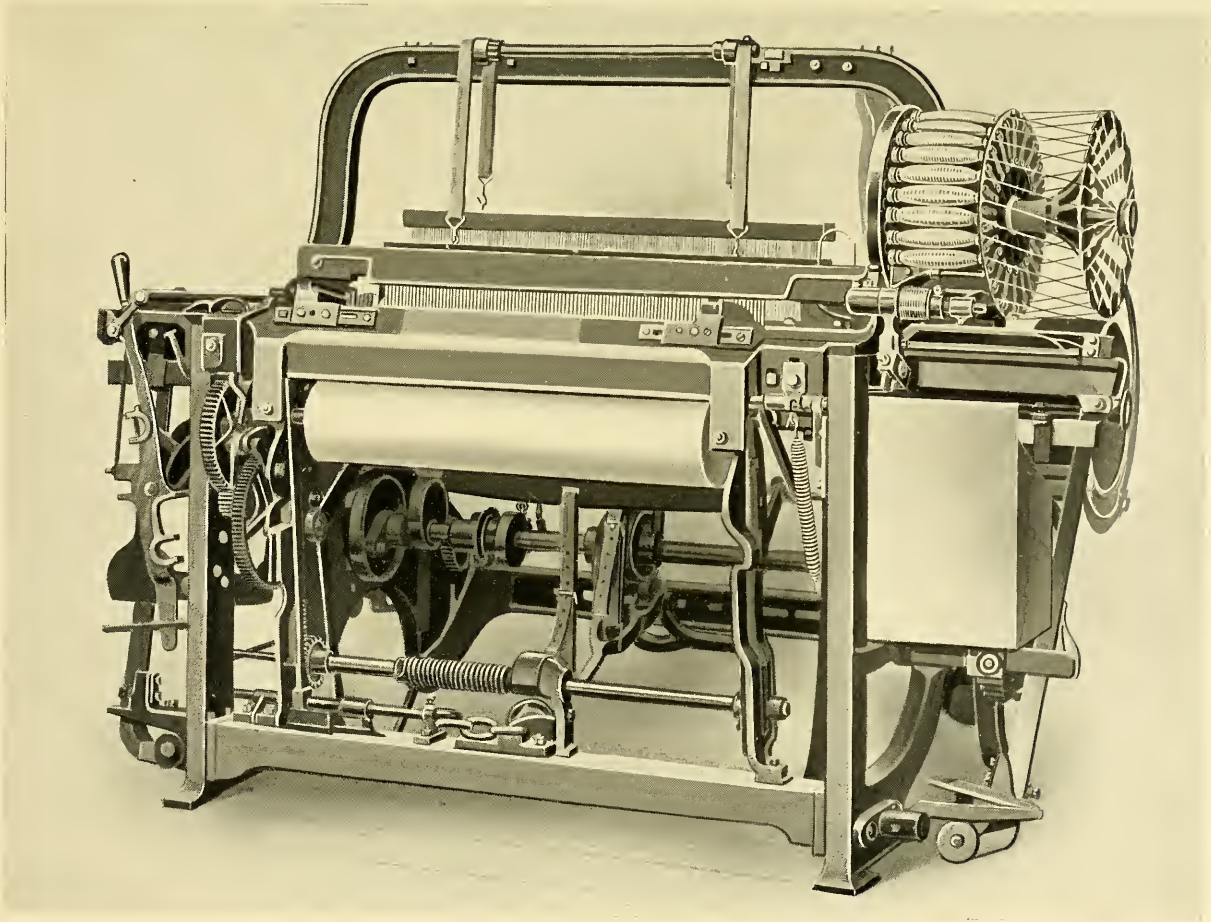


Fig. 351.—Northrop Loom: Details of Connection

small springs. From the boss of the disc holding the tips of the spools another and smaller disc projects, and over it a thread from each spool is tightly drawn. A pair of pawls, one on each side of a ratchet on the spindle of the hopper, govern its rotation. The undermost spool on the hopper is directly over the shuttle box below, guiding finger and levers vibrating in touch with it, ready to thrust the spool down into the shuttle at the impulse of the weft-changing shaft.

Weft-changing Feeler.—The instruments which cause the changes of spool are at the other end of the shuttle race from the weft carrier or hopper. A thin brass plate is mounted on a sliding shaft covered with a spiral spring; at the base of the plate sits an adjustable screw on the head of a cranked trip lever, one arm of which is passed through



NORTHROP LOOM

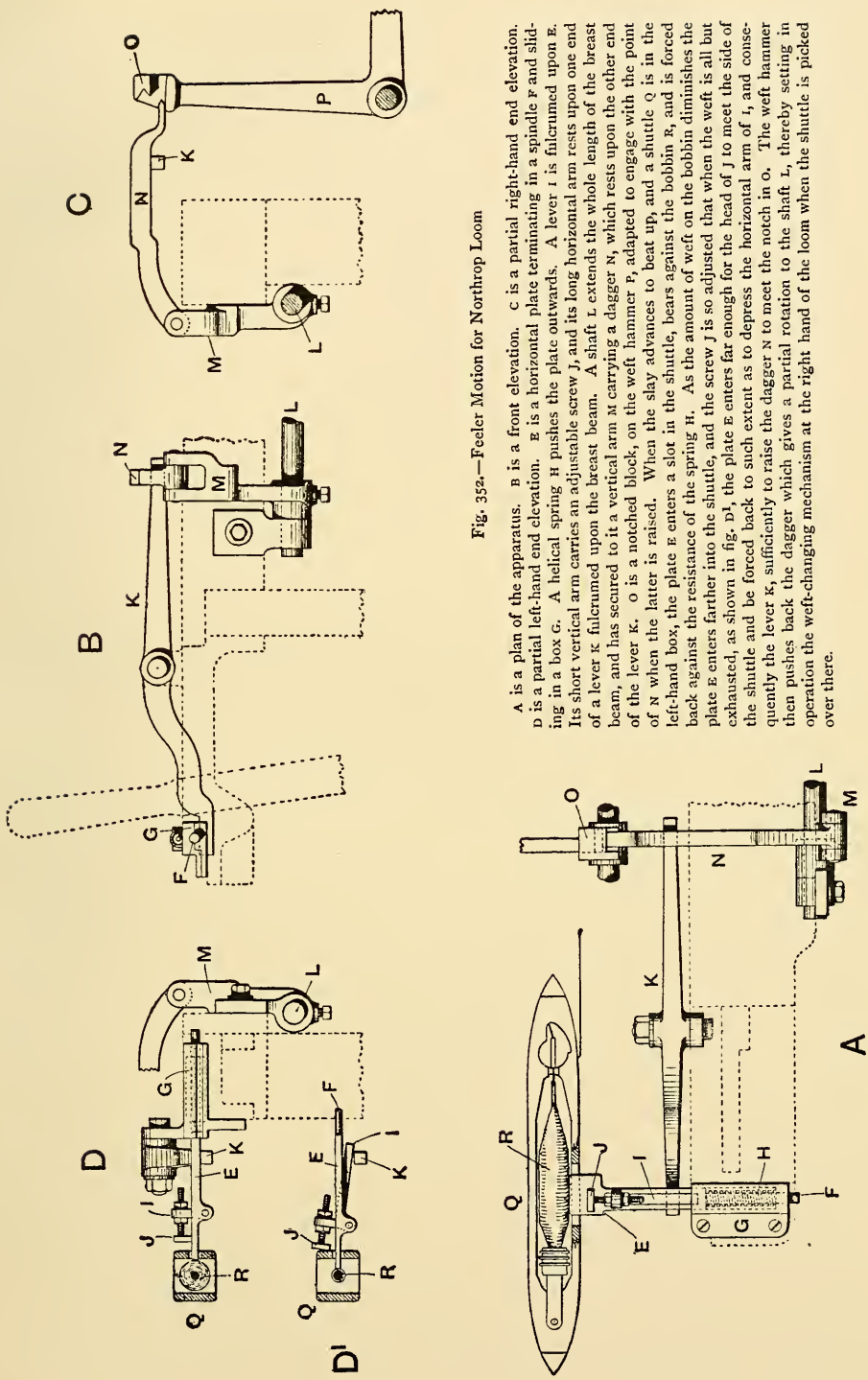


Fig. 352.—Feeler Motion for Northrop Loom

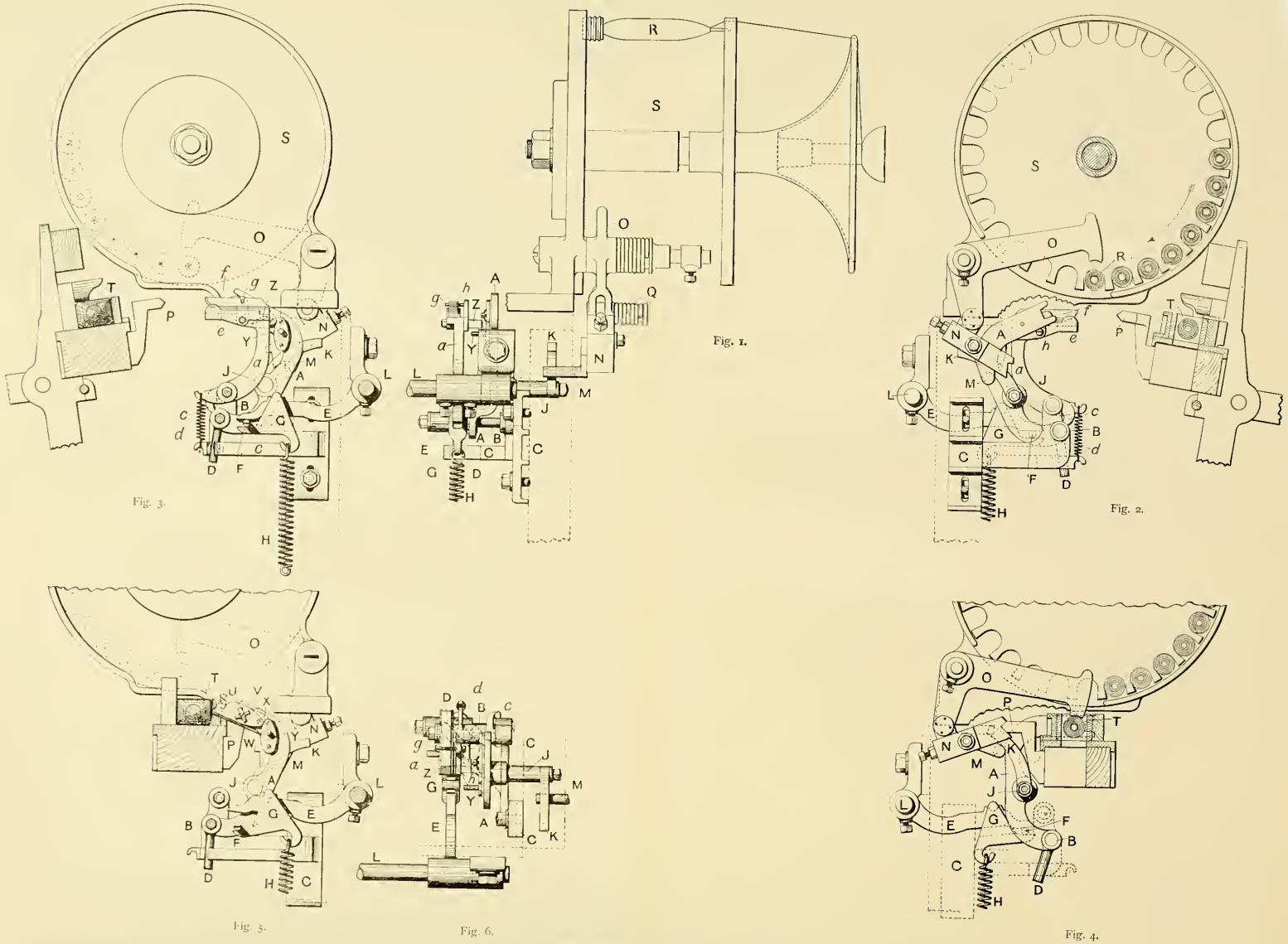
A is a plan of the apparatus. B is a front elevation. C is a partial right-hand end elevation. D is a partial left-hand end elevation. E is a horizontal plate terminating in a spindle F and sliding in a box G. A helical spring H pushes the plate outwards. A lever I is fulcrumed upon E. Its short vertical arm carries an adjustable screw J, and its long horizontal arm rests upon one end of a lever K fulcrumed upon the breast beam. A shaft L extends the whole length of the breast beam, and has secured to it a vertical arm M carrying a dagger N, which rests upon the other end of the lever K. O is a notched block, on the weft hammer P, adapted to engage with the point of N when the latter is raised. When the slay advances to beat up, and a shuttle Q is in the left-hand box, the plate E enters a slot in the shuttle, bears against the bobbin R, and is forced back against the resistance of the spring H. As the amount of weft on the bobbin diminishes the plate E enters farther into the shuttle, and the screw J is so adjusted that when the weft is all but exhausted, as shown in fig. D1, the plate E enters far enough for the head of J to meet the side of the shuttle and be forced back to such extent as to depress the horizontal arm of I, and consequently the lever K, sufficiently to raise the dagger N to meet the notch in O. The weft hammer then pushes back the dagger which gives a partial rotation to the shaft L, thereby setting in operation the weft-changing mechanism at the right hand of the loom when the shuttle is picked over there.

a slot in the shank of the brass plate or feeler (fig. 352). Through a series of connecting levers the lever in the slotted shank of the weft feeler is brought into relation with the hammer of the weft-fork lever on the one end and the shaft of the spool changer on the other. So long as the weft spool is covered with weft the brass-plate feeler is thrust back; every time the shuttle comes into the box underneath the feeler, the latter thrusts its nose into the shuttle. When the feeler meets with no resistance it goes full length into the shuttle, and the head of the screw on its shank comes into violent contact with the shuttle. Hitherto inactive, the levers connecting weft-fork hammer and weft-changing shaft now come into play. With the next stroke of the hammer the shaft makes a partial revolution and brings the weft-changing levers at the other side of the loom, and underneath the hopper, into action.

Action of Spool-changing Mechanism.—A finger on the end of the shaft, vibrated by the feeler through the connections described, acts upon a series of springs and levers which carry the motion up to the rods and guides which push the weft spool into the shuttle. When the fresh spool is pushed into the shuttle, the spent or broken spool is thrust out and passes down into a receiver below the shuttle box (see folding Plate).

Weft Cutter.—On the same shaft a projecting lever bears two small pieces which form between them a groove for a pin to slide in, the pin being cast upon the side of the weft cutter (see folding Plate). This is a lever held in a slotted bracket, over the shuttle race, on the inner side of its head a thin steel blade which acts in conjunction with a fixed block behind as the weft cutter. Between the cutter and the threaded disc a pair of cloth-covered pieces of wood, called *holders*, keep the weft at tension as the spool is being driven into the shuttle. The cutter intervenes, and snips away the floating thread, leaving just length enough to be taken into the nipper on the edge of the cloth. A stroke of the picker takes the shuttle once more into action.

Weft-fork Motion.—One of the merits of the Northrop loom is that, though the weft-fork motion acts in stopping the loom, it also brings the weft-changing mechanism into action, thrusting the spool with the broken thread out of the shuttle and inserting a fresh spool. By means of a lever loosely mounted on the shaft of the weft-changing appliance, the hammer of the weft fork causes the shaft to rotate in the same manner as does the feeler. The crossing weft again lifts



THE NORTHROP LOOM

Combined Shuttle Protector, Weft Cutter, and Weft Holder

(For description see pages 175–6)

the fork and allows the loom to start once more. In fact, the action of the weft fork is more direct. But, despite that advantage, the feeler motion is the better, because it acts before the weft has ceased to cross the loom, maintaining the continuity. On the contrary, the weft fork cannot act till the weft has shown that it is broken, and the consequence is broken picks, cracks, and thin and thick places in the cloth. It may be objected, however, that breaks in the weft are more frequent than emptied spools. This shows that both motions are needed, but it also indicates a defect in the loom.

Shuttle, Shuttle Box, and Spool.—A common shuttle is solid, but the function of the Northrop shuttle could not be discharged by an ordinary shuttle. During the short time it has been in use the Northrop shuttle has been altered many times. We take the latest model in use. In general shape it resembles the old hand-loom shuttle. At the butt end, however, instead of the simple cop skewer, we find a steel plate coming down from the upper surface into the centre of the opening. Coming out from under the plate, and deeply embedded in the wood, is the shank of a forked clip spring, with four points grooved annularly, and designed to hold the head of the pirn, which impinges the springs against the sides of the shuttle. In the tip of the shuttle a brass plate containing a diagonal slit is set. Underneath, the slit is continued, shaped like the barb of a hook, so that what goes in cannot come out, and at the tip of the barb is the shuttle eye.

The spool is a reversion to the very oldest kind of pirn, made of wood, with heavy head and a hollow at the tip. Round the head four rings of steel are fixed. The metal plate at the base of the shuttle assists in guiding the head of the spool into the grip of the forked clip, the annular grooves of which clasp tightly the rings on the head of the spool. The floor of the shuttle box has a hole cut through the centre of it capable of letting through a full spool, should it be thrust down out of the shuttle and ejected to make room for another.

All these appliances, it will be seen, have been carefully devised to aid the operations of the weft-changing mechanisms. The spool changer thrusts a spool from the hopper down into the shuttle; the back plate helps to guide it into the forked spring clips; the rings on the head of the spool are clasped in the annular grooves of the springs; the clip of the weft holder keeps grip on the weft thread, and aids in putting it into the slit of the shuttle plate, while the

motion of the shuttle itself draws the thread farther in and brings it down into the shuttle eye. The open floor of the shuttle box lets the ejected spool fall freely into the receptacle below.

Other Automatic Looms.—Though it is coming largely into use, we do not think the Northrop the last word in automatic looms. Even at the present time rivals are in the field, and, unless rumour is more than usually unreliable, others are coming. Imitations may be obtained from many loom builders. More interesting, however, are those which differ in important particulars from the Northrop. Two of these definitely known and offered to manufacturers even before the advent of the Northrop loom are called the one the "Burnley", and the other the "Seaton" loom. The former resembles the Northrop in principle, but the latter introduces a new idea altogether, or, perhaps, an old idea newly applied.

The Burnley Loom.—The special feature of the Burnley loom is the employment of weft cases instead of spools in the changing apparatus. The shuttle is hollow, carrying nothing but springs; the weft cases, patented by M'Farlane in 1857, contain the yarn. A cast-iron hopper containing a supply of these cases sits on the breast of the loom. On each side of the hopper a vertical slide is mounted, and the slides between them hold a cradle which keeps the cases in position, one case always lying ready to drop from the hopper. The bottom of the shuttle box is cut away and formed into a slot curving up to the front of the slay, where two spring fingers project outwards to the hopper. When the weft fails, from any cause, the weft fork acts upon the vertical slides of the hopper, calling down a weft case into the mouth of the slot. The pressure of the slay comes upon the dropped weft case and drives it upwards into the shuttle, forcing out the spent or broken weft case. As soon as the weft case has been placed, the loom resumes working.

The Burnley loom seems likely to be further developed and play an important part in competition with the Northrop, though the details of the mechanism leave something to be desired.

Seaton Loom.—The special feature of the Seaton loom is the weft carrier which takes the place of the shuttle. This is a double clip which travels across the loom, each end bearing a weft thread. Weft bobbins stand at both sides of the loom, and from the bobbins the yarn is led through a guide eye into a tube charged with clearing and regulating gears; thence the weft passes into a measuring and tensioning apparatus the functions of which are the paying out of exactly

the length of weft thread required, feeding it to the carrier, and cutting off from the spool. The carrier, thus fed, takes the weft thread through the warp shed, inserting a pick of weft; at the other side of the loom the carrier finds another pick, which it also inserts on its way back. In other respects the Seaton loom differs nothing from the common form of power loom.

Hall's Patent Automatic Weft Supply.—Perhaps the most remarkable and the simplest of the many automatic weft-changing appliances invented is that made by Messrs. Robert Hall & Sons, Ltd., Bury, patented in 1909. On the head of the slay cap at one side of the loom a rectangular frame capable of holding a dozen shuttles, placed one above the other, is fixed. At the base of the magazine, as it may be called, a pin projects from the slay. Round this pin the end of weft from each shuttle is wound as it is laid in the magazine. The shuttle box adjacent to the magazine is movable, and pinned on to a lever, which not only lifts it up, but tilts it over, sending out the spent or broken-wefted shuttle into a hopper at the side; the shuttle from the magazine descends into the empty shuttle box, which is brought back to a level again. The shuttle box then sinks back to the race, and the loom starts off once more. The agent in these actions is the weft-fork and stopping-rod mechanism. When the thread breaks or gives out, the weft fork drops, momentarily stopping the loom; the other mechanisms then come into play, lifting up the shuttle box, tilting it over, bringing out the shuttle from the magazine, guiding it into the box, and letting the box fall again. With the descent of the shuttle box the loom is set going. The pin in front of the slay holds the weft thread taut till after it has crossed the shed. The appliance can be put on any loom.

THE NORTHROP LOOM

Combined Shuttle Protector, Weft Cutter, and Weft Holder.

The following is a description of the double plate at page 172:—

Fig. 1 is a front elevation.

Fig. 2 is a right-hand end elevation.

Fig. 3 is a left-hand end elevation.

Figs. 4 and 5 are similar views to figs. 2 and 3 respectively, with the parts in different positions.

Fig. 6 is a part plan.

The shaft L (extending the whole length of the breast beam) is a continuation of the shaft L shown in fig. 352.

A is the combined shuttle protector and weft cutter, pivoted on a stud B carried by a bracket C. It has a pin D engaging in a diagonal slot in C, so that in rocking

forward it at the same time moves sideways on the stud B. An arm E, secured on the shaft L, rests upon a pin F in A. A triangular piece G is hung upon E, and has a projection bearing against the under side of F.

A spring H is so attached to G that it causes G to press upwards against F. A rod J fixed to A carries a curved finger K, which bears against a pin M on the piece N hinged to the lower arm of the transfer hammer O. The inner end of N has a notch adapted to receive the nose of the piece P fixed to the shuttle race. A coiled spring Q causes the pin M to press against the finger K.

The action of the protector A is as follows. Assuming that the weft in the shuttle is exhausted, and that the shaft L has been partially rotated by the action of the feeler or the weft fork, the arm E rises (see figs. 4 and 5), leaving A free to be moved towards the race by the combined action of the piece G, actuated by the spring H, and the piece N, actuated by the spring Q. Now, if the shuttle T is properly boxed, and therefore in the correct position to receive a fresh cop or bobbin R from the battery S, the protector A passes freely over the race and allows the piece N to rise to such a height that the nose of P meets it as the slay comes forward, and thereby forces down the transfer hammer O, inserting a fresh cop into the shuttle T, and at the same time forcing out the exhausted one. The position of the parts in such action is shown in fig. 4. If, however, from any cause the shuttle is not fully home in the box, the protector meets the shuttle (see fig. 5) and is unable to move farther over the race, consequently the very slight movement permitted to N is not sufficient for it to meet P, and therefore the hammer is not actuated, and no transfer takes place.

A plate U is pivoted on A and pressed against a fixed plate by the plate V and spring W. These plates form the weft cutter. The plate U has an extension X, carrying a pin Y adapted to make contact with an inclined plate Z on the weft holder *a*.

As A moves towards the race the pin Y passes under Z and moves the plate U, so that the cutting jaws are open to receive the weft. As A goes back Y passes over Z, which closes the jaws (see figs. 3 and 5) and cuts the weft near the shuttle. The other end of the weft is severed close to the selvage by a cutter on the temple. The piece of weft thus detached is caught by the weft holder *a*, and thus risk of weaving it into the cloth is avoided. *a* is pivoted on a stud carried by the bracket C, and is free to move back, but is driven forward against a stop *c* by a spring *d*. The thread-catching jaws consist of two pieces of wood, *e*, *f*. *e* is seated on *a*, so that it has a short rocking movement, and *f* is held upon it by a pin *g* in a bell crank *h*. This bell crank carries the inclined plate Z. The jaws, *e*, *f*, are faced with velvet or some other suitable material. Each time the pin Y passes over Z the jaws are thereby opened to receive the weft, and they close down on it by the action of a spring.

In figs. 4 and 5 the weft holder is omitted for the sake of clearness.

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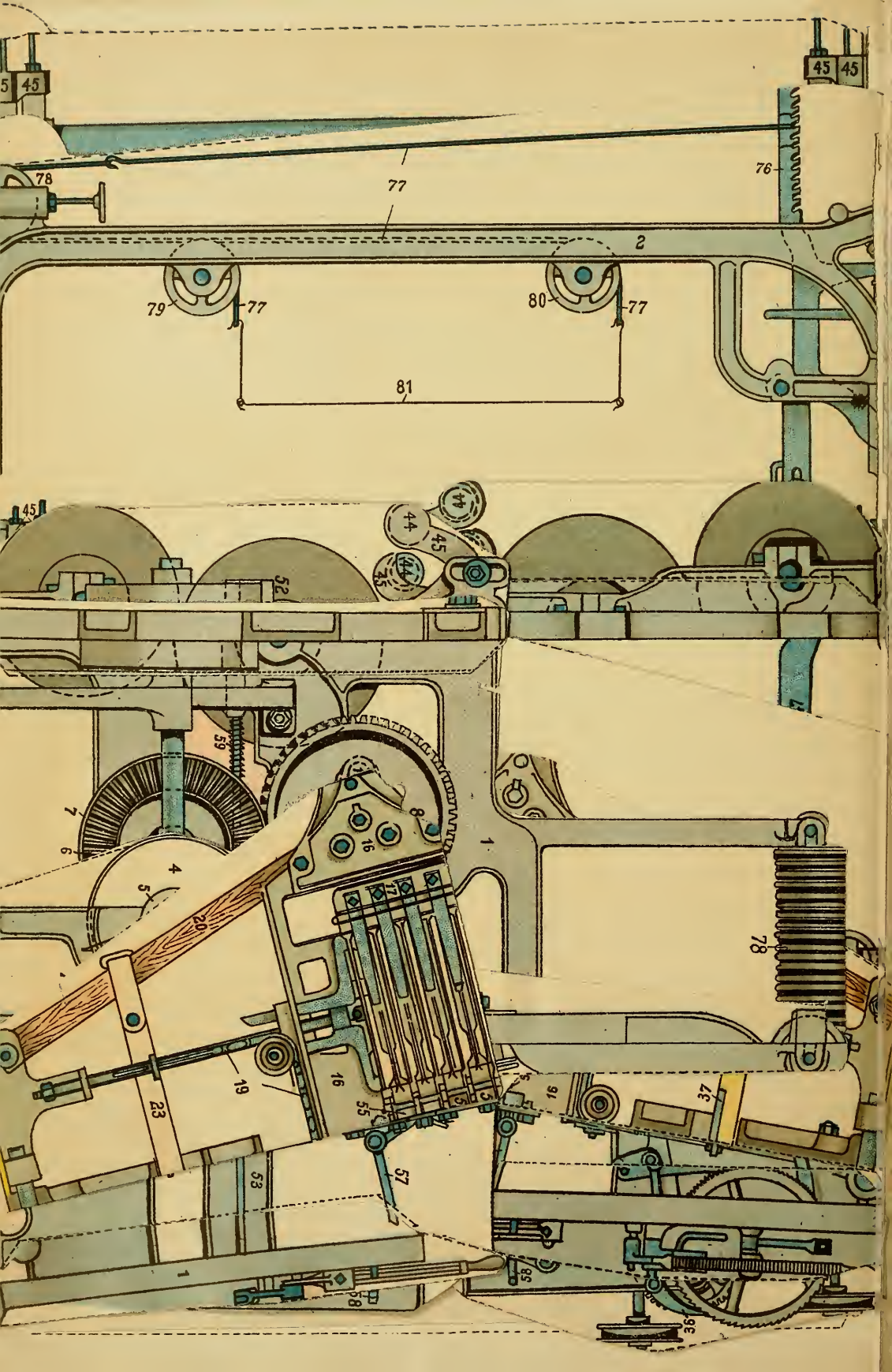
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MODEL OF OPEN-SHED DOBBY LOOM

Directions for Erecting Model of Loom.—Lift the two sides of the loom into an erect position. Bring the breast beam (38) up to a level with the starting handle (51) and insert white tabs into openings on both sides. The going part, containing shuttle race (13), reed (14), and sley cap (15), can now be erected to stand in line with the shuttle-box frames (16), which should have been brought out from the sides to show the shuttle boxes (17), chains and boxes (18, 19), and picking shafts (20), with gearings, the tabs fitting easily into the sides at the proper positions. Next, lift the bridge of the central frame (2) up to a level with the numbers corresponding in the side frames, and fix with tabs. Pull out the two pieces on the right-hand side of the frame, containing upper cylinder (62), lower cylinder (63), and other parts of the dobby mechanism, and cause to stand out in line with the bridge (2). By setting the small piece parallel with the larger, we obtain a clear view of the whole dobby and shedding appliances, with all their connections. To complete the loom, lift up the back piece, containing upper and lower warp beams (39, 40), tubular back beams, &c., and fit with the tabs on to the sides at the points indicated.

Key to Reference Numbers

1, 1, 1. Lower framing.
2, 2. Upper framing, carrying dobby mechanism, &c.
3, 3, 3. Cross girders of frame.
4. Fast and loose belt pulleys.
5. Bevel pinion on driving pulley shaft.
6. Bevel wheel, driven by bevel pinion 5.
7. Spur wheel (behind bevel wheel 6) on low shaft 25.
8. Spur wheel on crank shaft, driven by spur wheel 7.
9. Crank shaft.
10, 10. Cranks driving slay.
11, 11. Connecting rods to swords.
12, 12. Swords.
13. Shuttle race.
14. Reed.
15. Sley cap.
16, 16. Shuttle-box frames.
17, 17. Shuttle boxes.
18, 18. Chains and rods actuating right-hand shuttle boxes.
19, 19. Chains and rods actuating left-hand shuttle boxes.
20, 20. Picking shafts.
21, 21. Rock shafts.
22, 22. Arms on rock shafts 21, 21, connected to picking shafts by straps 23, 23.
24, 24. Sliding cams on low shaft 25 operating rock shafts 21, 21, through arms 26, 26.
27. Spring and straps 28, 28, connecting lower ends of picking shafts, to return them to normal position after picking.
29. Cloth roller.
30. Ratchet wheel, operating cloth roller through pinion 31 and spur wheel 32.
33. Pawl operating ratchet wheel 30, through medium of weight 34 and levers 35.
36. Back stop pawl to ratchet wheel 30.
37. Pin on sword drawing back weight 34 and pawl 33 as slay retires, weight operating cloth rod as slay returns.
38. Breast beam.
39. Upper warp beam.
40. Lower ,, ,,
41, 41. Worm wheels on warp beams, operated by worms 42, 42, on shafts 43, 43. These are actuated by the movement of the slay.
44, 44. Tubular back beams, carried in levers 45, 45, and operated by weights 46, 46, 46, 46 on levers 47, 47, through bell cranks 48, 48, and rods 49, 49, 49, 49, 49.
50. Shaft carrying starting handles 51, 51, operating bell fork 52, through rod and link 53.
54. Shaft on shuttle race, with arms 55, 55, operated by shuttle-box swells 56.
57, 57. Daggers on shaft 54, which, when shuttle is not properly housed, press on levers 58, 58, which throw handles 51, 51 back, thus permitting spring 59 to throw belt from fast to loose pulley and stop loom.
60. Lever on shaft 50, operated by a central weft fork at 61, to stop loom when weft breaks, or is absent. (Weft fork is not shown on drawing.)

DOBBY MECHANISM

62. Upper cylinder. } These cylinders have inter-
63. Lower ,, } rupted teeth and are driven from the crank shaft 9 by spur gears 64, 64, mitre gears 65, 65, 66, 66, and 67, 67.
68. Clutch, operated by lever 69 to connect or disconnect cylinder motion.
70. Dobby chain, driven by pinions 71, 72, and spur wheel 73 from lower cylinder 63.
74. Nest of spur wheels, with interrupted teeth, carried on vibrators 75, the latter being actuated by dobby chain.
76. Jacks operated by links from wheels 74, as latter are partially rotated by upper or lower cylinders 62 or 63.
77. Cords from upper ends of jacks, passing round sets of guide pulleys 78, 79, 80.
81. Rods suspended from cords 77, to carry upper heald shafts.
82, 83. Sets of guide pulleys for cords from lower ends of jacks to connect to lower heald shafts.
84. Chain controlling shuttle boxes and picking motion.
85, 86, 87. Levers operated by chain 84, through medium of wheels 88 and cylinder 62, 63. Some of these actuate the chains and rods which move the shuttle boxes.
89, 89. Levers connected by rod 90 and operated by rod 91 from part of above motion to control picking cams 24, 24.

SOUTHEASTERN MASSACHUSETTS
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The textile industries